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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XLIII.—*Topographic Development of the Triassic Formation of the Connecticut Valley;* by WILLIAM MORRIS DAVIS.

[Published, as far as relates to work done for the U. S. Geological Survey, with the permission of the Director.]

CONTENTS :—Itinerary of Harvard Summer School of Geology—Faults in the Meriden region—Cross-section of the District—Means of detecting the unfaulted sequence of Triassic beds—Mechanism of monoclinal faulting—Topographic development of the Triassic belt—Initial constructional stages represented by the faulted blocks of Southern Idaho—Mountain ranges of the Great Basin equivalent to a later Jurassic Stage—The whole region base-leveled in late Cretaceous time—The present valleys worn in the Cretaceous base-level plain after its elevation—Polygenetic topography—The origin of the Connecticut river outlet via Middletown—The Connecticut river was originally consequent on the monoclinal faulting, and still persists near the course then taken, but has entered a second cycle of life as a result of the elevation of the lowland that was produced in its first cycle.

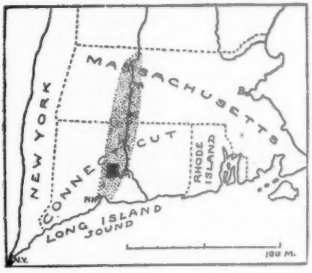
SINCE presenting two years ago a suggestion to account for the mechanical origin of the faulted Triassic monocline* I have visited the region about Meriden with the Harvard Summer School of Geology during its sessions of 1887 and 1888. An itinerary of the excursions made by the school in

* This Journal, xxxii, 1886, 342–352; Proc. Amer. Assoc., xxxv, 1886, 224–227; Seventh Ann. Report U. S. Geol. Survey, 1886, just issued.

deciphering the structure of the district together with maps and sections to illustrate the facts of observation and a detailed consideration of the arguments leading to certain conclusions is now in press in the Bulletin of the Museum of Comparative Zoölogy at Cambridge. The structural problems of the region afford excellent opportunity for practical instruction in geology. A brief summary of the results reached is presented here.

The small black square in figure 1 indicates the position of the Meriden district in central Connecticut and in the southern part of the New England Triassic area. Figure 2 is the same

1.



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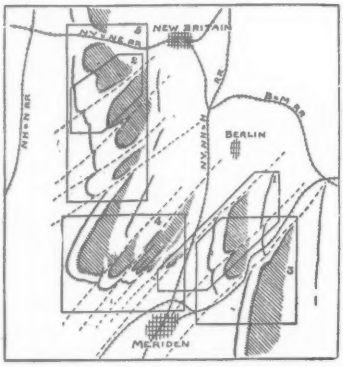
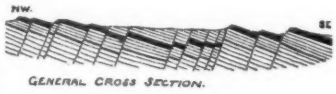


district on a larger scale. The main trap sheet, whose monoclinal ridges dominate the relief of the region, is shaded with oblique lines; the subordinate ridges formed on the anterior and posterior trap sheets are indicated by lines on either side of the main ridges. The chief faults of the region are drawn in broken lines, and their general southwest trend is clearly seen. The several enclosed spaces numbered 1 to 5 mark the areas represented on maps of still larger scale in the Bulletin above referred to. The "mountains" formed by the main trap sheet are, beginning on the southeast: Higby (or Besick) Mountain, Chauncy Peak and Lamentation Mountain, the Hanging Hills group northwest of Meriden (consisting of Cat-hole Peaks, Notch Mountain and West Peak), Short Mountain, High Rock and Shuttle Meadow Mountain, and Bradley's Mountain, before coming to Cook's Gap, a pass followed by the New York and New England railroad westward from New Britain. The evidence seems to me very strong that the faults separating all these blocks were produced after the trap sheets had taken their place in the stratified series, all the sheets here shown being extrusive surface flows, poured out during the accumulation of the aqueous strata.

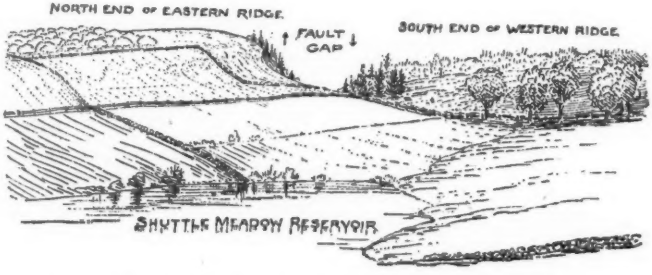
A cross-section of the district from northwest to southeast, on the scale of figure 2, is given in figure 3; but its construction is not very accurate as to the values of dip and dislocation. The heave of the faults is on the southeast in every case, with the single exception of the fault between High Rock and Short Mountain, where the heave is on the other side; this departure from the prevailing rule of dislocation being indicated by a corresponding departure from the prevailing rule of topography. In passing northward across a fault of the ordinary kind, the repeated portion of a ridge is found in what Percival called "advancing order," that is, farther west than before; but here the repeated ridge is found in "receding order," and hence the fault is known to have a reverse throw. The distinct topographic effect of the faults is illustrated in two figures. The first (fig. 4.) is a view southwestward through a gap in the anterior trap ridge, on the line of the fault that

3.



GENERAL CROSS SECTION.

4.



runs from New Britain through Shuttle meadow reservoir. The heaved side of the fault is on the left (southeast), where the back of the ridge is shaded by an apple orchard and its outcrop bluff is clothed with hemlocks: the thrown side is on the right, where the trap sheet lies lower, but rises westward to another ridge like the first; an old pasture field on its back, and a bold cliff facing the broad Southington valley beyond. This cliff runs two or three miles north, but shortly turns around the southern end of the ridge where it is terminated by the oblique fault; the other ridge falls away to the left of the view as it approaches the fault, but continues southward till it is again broken by another fault, and the topographic dislocation is repeated.

The second view (fig. 5.) is of larger range: it is taken from a hill about a mile east of Berlin, looking south to two masses

of the main trap sheet. Lamentation Mountain is on the right with the slightly detached Chauncy Peak rising a little over its farther end; and Higby (Besick) Mountain rises on the left. The strong fault that passes a little east of Meriden separates

5.

HIGBY AND LAMENTATION MOUNTAINS.

these two mountains, while the greater fault which runs west of Meriden cuts off the north end of Lamentation. The view of these mountains is highly suggestive.

The extension of the faults to the northeast and southwest of the trap ridges is seldom traceable very far. Southwest of the anterior trap ridge, the country is generally soon covered with drift; but occasionally certain beds of conglomerate serve to indicate the course of a fault, as is the case with the great fault between the Hanging Hills and Lamentation Mountain, which may be followed two miles southwest of Meriden. To the northeast, the occurrence of a second posterior ridge in certain localities may in time serve to unravel the fault lines, as it has already for the fault between Chauncy Peak and Higby Mountain, which is thus traced about three miles to the northeast of the gap that it produces in the main sheet. All these localities are given in detail in the itinerary of the summer school, as above.

The systematic arrangement of the faults in this district, already mentioned in earlier papers, is thus confirmed. When this is once perceived, it is evident that the normal sequence of the Triassic beds can be found only by crossing the monocline obliquely to the northeast, always keeping within the limits of a single fault-block. This seems to me to be the key to the structure of the region. The remainder of this paper is occupied with considerations not discussed in the Bulletin.

The mechanism suggested to account for the production of a monocline with its system of faults thus arranged has been in the mind of other writers. Some fourteen years ago, Mr. G. K. Gilbert conceived its essential features, and gave a brief account of it in his description of the Great Basin Ranges.* He made the theoretical suggestion "that in the case of the Appalachians, the primary phenomena are superficial; and in that of the Basin Ranges they are deep-seated, the superficial being secondary; that such a force as has crowded together the strata of the Appalachians—whatever may have been its

* Wheeler's Surveys west of the 100th Meridian, iii, 1875, 62.

source—has acted in the Ranges on some portion of the earth's crust beneath the immediate surface; and the upper strata, by continually adapting themselves, under gravity, to the inequalities of the lower, have assumed the forms we see. Such a hypothesis, assigning to subterranean determination the position and direction of lines of uplift in the Range system, and leaving the character of the superficial phenomena to depend on the character and condition of the superficial materials, accords well with many of the observed facts, and especially with the persistence of ridges where structures are changed." The essential peculiarities of the method for the production of a faulted monocline is here clearly stated, although no opportunity is noted for independent verification of the suggestion, such as appears in Connecticut in the correspondence between the course of the faults and the trend of the underlying schists.

In my previous paper concerning the origin of the faulted monocline, no special consideration was given to the cause of the discordance between the course of the faults and the strike of the beds in the Meriden region, which now appears as so strong a structural characteristic. It may be suggested that this is the result of a force of compression acting on the whole mass of crystalline and overlying rocks in a direction oblique to the strike of the schists, whose structure determines the course of the faults. The schists trending northeast and the compression being exerted from west to east so that movement of any point in the schists must take place in an east and west vertical plane, a result such as that which here obtains might be produced. A consequence of this would appear in the much greater uplift given to the southwestern than to the northeastern part of any block thus obliquely tilted; but the unworn surface of any block would slope eastward, in the direction of the dip of its beds. When deeply eroded, the older members of the series of tilted beds would be revealed in the southwestern part of the block; while the newer still remain in the northeastern part, as we find them.

The topographic development of the Meriden region and indeed of the valley as a whole, may be briefly sketched. Its early structural topography, such as would have resulted from its dislocation without erosion, finds modern illustration in the tilted lava blocks of Southern Idaho, as described by Russell. This writer, from whose vivid descriptions we derive so clear a picture of our western country, says that the whole of the Great Basin—the "immense region lying between the Sierra Nevada and the Rocky Mountain systems has been broken by a multitude of fractures, having an approximately north and south trend, that divide the region into long, narrow, oro-

graphic blocks. These have been tilted so as to form small but extremely rugged mountain ranges, often from fifty to a hundred miles in length, with a width of but a few miles."—The fractures by which the blocks are separated "are of a comparatively recent date, and present bold scarps, that are frequently but slightly scarred by erosion, while the most recent examples of all were unquestionably formed within the past few years, and are yet unclothed by vegetation." . . . "The exhibition of fault-scarps, tilted blocks, and sunken areas, to be seen at the southern end of the Warner Lakes, is the most interesting of its kind that it has ever been our privilege to examine. In this narrow zone, the orographic blocks of dark volcanic rock are literally tossed about like the cakes of ice in an ice-floe; their upturned edges forming bold palisades that render the region all but impassable." . . . "These fault-scarps rise in sheer precipices that overshadow the Warner Lakes throughout their entire extent. Toward the northern end of the valley the great fault-scarp forming its eastern wall sends off a number of branches, at quite regular intervals, with a general northwest trend. The blocks thus separated pass under the lake beds that floor the valley, and appear again on its western border, where they form cliffs of considerable height." . . . "It is between the high walls enclosing the southern portion of the valley that the greatest confusion of the minor blocks is to be seen. Many of these fragments measure a mile or so on their edges and are tilted in various directions, leaving narrow rugged valleys between their upturned margins. The diverse tilting and the numerous fault-scarps that rise without system into naked precipices combine to make this a region of the roughest and wildest description." (Fourth Ann. Report U. S. G. S., 443, 445, 446.)

It is apparent from these extracts and from others that could be quoted that while southern Oregon has a more complicated structure than that of the Connecticut Trias, it nevertheless serves admirably as a picture of the early stages of the latter, when its faults were still growing: except in the matter of diverse displacement and in the amount of erosion suffered, the description of these long narrow blocks might apply to those of the Connecticut valley.

The blocks in Idaho have been dislocated so rapidly and so recently that they preserve their constructional topography with insignificant alteration, and in this they are the best examples of any region yet described. Nowhere else can we find so good an illustration of a mountain system in its infancy —almost in its birth. A similar constructional topography probably once existed in Connecticut; but it has long since disappeared. The upper surface of the Triassic region being

of shales or sandstones, instead of hard sheets of lava, presumably allowed erosion to follow displacement rapidly, but it seems highly probable that the topography of the region was for a considerable time closely consequent on the deformations that closed the period of deposition and ushered in the long cycle of erosion that has since then endured with little interruption.

As time went on and the forces of deformation slackened, the forces of erosion made better headway in reducing the region to a water-sculptured topography; we find existing illustration of this stage of the history of central Connecticut, in the present form of the central ranges of the Great Basin. The following description is also condensed from accounts by Russell.

The central ranges of the Great Basin are structurally composed of long narrow blocks of bedded, aqueous and igneous rocks separated by faults and tilted into monoclinal attitudes; but the simple original structural form that they may once have had is now no longer immediately apparent; the orographic blocks here have been long enough exposed to denudation to reduce them to a water-sculptured form, in which the slopes are trenched by numerous ravines, and the ridges are notched by passes which break the crest-line into peaks, and everywhere develop topographic detail dependent on the unequal hardness of the bedded components of the mass. Much of the detritus taken from the upper portions is now lodged in the depressions between the adjacent ranges. Variety of form has thus been gained, and a marked feature of this variety is that it all tends to the better collection and discharge of the rain that falls upon the ranges. The topographic variety is now near its fullest development, and with further denudation it must lose strength; the ravines will consume more of the mass, the passes will be lowered and the peaks will be attacked and reduced from all sides. The original structural form will be then even less distinct than now, and a continually closer approach will be made to the ultimate featureless base-level lowland, to which all land forms are in time reduced, if no disturbance, such as elevation, interrupt the normal simple progress of their geographic evolution.

Some mountainous variety of form must in a similar manner have obtained for a time in central Connecticut and Massachusetts, when the strongly faulted monoclinal blocks were laterally furrowed by ravines and notched by passes. This may be provisionally called the Jurassic stage of the evolution of our district. But even mountainous ridges are not permanent. Given time enough, and the faulted ridges of Connecticut must be reduced to a low base-level plain. I believe that

time enough has already been allowed, and that the strong Jurassic topography was really worn out somewhere in Cretaceous time, when all this part of the country was reduced to a nearly featureless plain, a "*peneplain*," as I would call it, at a low level; a plain that was broadly uplifted in early Tertiary time—or thereabouts—and thus thrown into another cycle of destructive development, and whose elevated remnants are now to be recognized in the crystalline uplands on either side of the present Triassic valley of Connecticut and Massachusetts (Emerson), and in the crest-line summits of the main trap ridges. The general equality of upland altitude on very diverse structures is the essential argument for the base-leveling of the region; but it is not intended to discuss this in detail at present. The post-cretaceous elevation that lifted the ancient lowlands was greater in the interior than near the coast, and our present valleys are deeply sunk and broadly opened in it. An extension of the same ancient lowland, now similarly elevated and dissected, is to be found in northern New Jersey. Standing on a commanding point of view, such as the fine drumlin a mile or more southeast of Meriden, whence the main trap ridges may be seen for many miles north and south, one must in imagination refill the low ground with the shales, sandstones and conglomerates that have been worn away, and thus raise the surface up to the level of the main trap ridges, or even a little higher, in order to perceive the form attained by the land in the late stage of the degradation of the dislocated Triassic blocks, when all this region stood lower. It was only after the close of this first cycle of degradation and after the elevation of the country to something like its actual altitude at a later date that the beginning of the present or second cycle of valley-making was reached. Some unmeasured part of the Tertiary and later time has been allowed for this part of the work. In the crystalline rocks, the valleys are narrow and steep sided, as is so finely shown in the expressive topographic map-sheets of western Massachusetts; but in the Triassic area, where the sandstones are relatively soft, the valleys have been widened out into broad lowlands, only the thicker trap-sheets retaining still some indication of their former altitude. The latest touches have been given to their form by glacial action, both destructive and constructive, as well as by river deposits in the valley bottoms and by estuary deposits in the coastal districts. Except in terrace and gorge cutting, post-glacial erosion is insignificant. If this sketch be correct, we may conclude that the present topography is not an immediate product of erosion on the Jurassic deformations of the Triassic beds; it is an uncompleted advance in a second cycle of development, with recent complications by glacial ac-

tion and slight changes of level. Like mountains of repeated growth, this topography may be called "polygenetic." The present form of the region is modeled with reference to at least two base-levels.

Just as southern Idaho and central Nevada furnish illustration of the initial and somewhat advanced topographic forms assumed in the development of our Connecticut district, so there will doubtless be found somewhere on the earth, regions of similar structure, presenting actual illustrations of its later stages, when its stronger forms were subdued and finally worn down to the featureless surface or peneplain of its old age. Thus the evolution of the region will be better understood. By this process of comparison,* we may not only restore in some measure the past history of our region, but may as well look into its possible future. When later elevation raises our eastern continental slope to still greater altitude and exposes the mass of the land to still deeper attack by erosive forces, it may happen that the base-level will take such a position as to allow the discovery of the ridges of fundamental crystallines between the fault lines at the base of the Triassic trough; and this stage has its forerunner in a district of northern China (Shantung), described by Richthofen.† The structure of the district is summarized as consisting of crystalline schists of steep dip, unconformably overlain by Cambrian sediments; this compound mass is broken by a system of sub-parallel faults running east or southeast, with upthrow on the southern side, and with a tilting of the faulted blocks by which the uncomformable cover of Cambrian sediments dips southward toward the faults. The deformation is ancient, and subsequent denudation has exposed the fundamental crystallines in long narrow ridges, which by their superior hardness have become water sheds (whether they have always been so or not does not appear, as the successive cycles of river history from the first to the present are not deciphered), while the Cambrian sediments remain in narrow monoclinal strips between every ridge and the next fault to the south. The bottom of our Connecticut trough may some day be worn into similar ridges and valleys.

* During the preparation of this paper, I have had pleasure in meeting evidence of the value of the method here outlined in an essay by Dr. V. Hilber of Graz, Austria In discussing the origin of cross-valleys, he suggests an inductive illustration of their development, as follows: "Auch eine Methode welche in der vergleichende Erdkunde noch kaum Anwendung gefunden hat, welche aber auch für andre Fragen derselben berücksichtigenswert erscheint . . . . ist das Aufsuchen derjenigen Oberflächenformen, welche als Entwickelungsstadien der vollendeten Erscheinung betrachtet werden können." Die Bildung der Durchgangsthäler, Pet. Mitth, xxxv. 1889, 15.

† China, II, 239. Fig. 56. See also Philippson, Studien über Wasserscheiden, 119.

There is a peculiarity of the drainage of the Triassic belt that perhaps finds explanation through considerations such as the above. The Connecticut river from where it receives the Passumpsic between northern New Hampshire and Vermont, follows a line of ancient slates that lead it southward with direct course to the Triassic formation in northern Massachusetts; it crosses this State with tolerably direct southern course and continues in much the same line across Connecticut as far as Hartford; but there it turns to the southeast, and at Middletown it leaves the soft Triassic rocks and enters the hard crystallines, which it follows through a deep and rather steep-sided valley to the Sound at Saybrook. This departure from the low escape now open to the river along the line of easy grades that is followed by the Consolidated railroad from Hartford to New Haven, calls for some special explanation. It is evidently an example of the same kind as those described by Jukes in his famous paper, "On the mode of formation of some of the river valleys in the south of Ireland." But it remains to be seen why the Connecticut should turn from the Triassic belt of soft sandstones which here might lead it to the sea, and why if so turning it should take a course to the southeast rather than to the southwest.

Let it be admitted for the moment that the present course of the river is in the main inherited from the course that it had at the end of the development of the Cretaceous lowland; and that the course that it had during this early cycle of development was consequent upon the original dislocations of the Triassic surface. It is natural enough that the initial drainage of a faulted area should be consequent; we have excellent illustrations of immediately consequent drainage in the lava block country of southern Idaho, already referred to. Now if we can independently determine the probable direction of consequent drainage immediately after the time of dislocation in the lower Connecticut valley, and if this correspond to the present course of the Connecticut where it turns from the Triassic to the Crystalline rocks, the explanation offered may be at least deemed worthy of further examination.

The simplest method of determining the direction of the initial consequent drainage of the dislocated Triassic surface involves a reconstruction of the primitive form that the surface would have had if its dislocation had not been accompanied by erosion; the "structural surface" of la Noë and Margerie. This may be done most easily by developing the surface of the great lava flow that we now call the main trap sheet; restoring its lost portions by extending it upwards into the air along the plane of its dip, and stripping it bare where still covered; but limiting every part of the reconstructed surface by the

fault planes that bound the several blocks. The original surface of the uppermost bed of sandstone would have been essentially parallel to this surface of the trap sheet, but a few thousand feet higher.

Percival long ago called attention to the great curve of the main trap sheet from the Hanging Hills to Mount Holyoke in Massachusetts. The restored surface of the sheet, although somewhat interrupted by faults, forms a great half-boat, with the keel along the line joining the ends of the curve and the western side of the boat following the main trap ridge. The boat may be enlarged by extending the sheet southeast from the Hanging Hills through Lamentation, Higby (Besick), Paug and Toket Mountains to the eastern margin of the Triassic formation north of Branford. In this portion of the curve, the faults are much stronger than farther north; but viewed in a large way, the whole sheet from Toket to Holyoke may be regarded as a somewhat broken half-boat, in the attitude already described, with the bow at Belchertown, Massachusetts, and the stern above Branford, Connecticut. Before the Cretaceous base-leveling was completed, the western side of the half-boat reached much higher into the air than the crests of the main ridges reach now.

The upper surface of the Triassic formation would have had a form similar to this, if not eroded. A drainage-system established upon it must have found outlet not to the west or south, where the side and the stern of the boat prevented discharge, but to the east, where the boat was open, and the location of the discharge would be somewhere about the lowest point of the keel. In other words, the chief stream of the region, during the early development of the dislocated country, would have run out to the east, some distance north of the point where the main sheet now reaches the crystalline rocks on the eastern margin of the formation. This corresponds with the general course of the Connecticut closely enough to give some degree of acceptance to the explanation; and the lower Connecticut may therefore be tentatively classified as an originally consequent stream, which has lived far through one cycle of life, and has now in obedience to the general elevation of its drainage area, entered a second cycle in which it is well advanced, still persisting more or less closely in the course chosen in its first cycle.

Thus explained, it may be called in this portion of its valley a revived river of originally consequent course. It is not intended to imply that the dislocated Triassic region ever had a purely "structural surface;" but only to indicate that the summation of all the movements of deformation, which would produce such a surface, sufficed to throw the drainage of the region into the area of least elevation.

The objection to the explanation does not seem to me to be in its inherent improbability, for I believe that every step in the process may find its homologue in the present stage of other regions of similar structure but less age. The objection lies rather in a difficulty not yet named; namely in the occurrence of a strong fault or series of faults, by which the eastern margin of the formation is determined, and whose upthrow is on the east. The drainage from the centripetal slopes of the Triassic half-boat must have surmounted this barrier in order to flow to Saybrook, and in doing so may have formed a large lake in the bottom of the boat, to be drained later on when the outlet was deepened. Whether suppositions so transcendental as these shall be approved remains to be seen.

Cambridge, Mass., February, 1889.

Art. XLIV.—*Analyses of three Descloizites from new Localities;* by W. F. Hillebrand.

[Read before the Colorado Scientific Society, Mar. 4th, 1889.]

1. *Mayflower Mine, Bald Mountain Mining District, Beaverhead County, Montana.*

Through Messrs. W. H. Beck and George E. Lemon of Washington, D. C., was received about a year ago for examination a large lump of friable, uncrystallized material, having a dull yellow to pale orange color, and consisting chiefly of a vanadate, but carrying a large percentage of gangue. Two samples as pure as could be selected from different parts of the lump were analyzed with the following results:

	I.	II.	Mean.	Molecular ratios.		
PbO	56·02	55·84	55·93	·2508		
CuO	1·16	1·13	1·15	·0145	·4718	4·02
FeO	0·70	0·70	0·70	·0097		
ZnO	15·96	15·91	15·94	·1968		
V_2O_5	----	20·80	20·80	·1140		
As_2O_5	0·32	----	0·32	·0014	·1173	1·00
P_2O_5	0·27	----	0·27	·0019		
H_2O	4·37	4·36	4·37	·2428	----	2·07
SiO_2	0·20	0·16	0·18			
CaO	0·10	----	0·10			
MgO	0·06	----	0·06			
			99·82			

From I 27·62 per cent of gangue insoluble in cold dilute nitric acid has been deducted, and from II 22·20 per cent: manganese was present in the gangue in small quantity, apparently as pyrolusite, but it was not dissolved by the acid. The insoluble portion was found also to retain very small quantities

of lead and zinc, which were estimated and included in the analysis as probably belonging to the vanadate. The water had to be estimated indirectly by deducting from the total amount of water afforded by the dried mixture of vanadate and gangue that belonging to the latter alone, which was found as follows. The mixture, dried at 100° C., was dissolved in cold dilute nitric acid, and the insoluble matter collected in a Gooch crucible was dried at the same temperature and then ignited. The loss on ignition gave the water in the gangue, there being no ferrous iron in the latter to influence the result. The traces of SiO_2, CaO and MgO may be neglected as probably derived from the gangue. The water, it will be noticed, is double that required by descloizite, $R_2(OH)VO_4$, but in view of the liability to error inherent in the method of water estimation employed this is not deemed sufficient cause for separating the mineral from descloizite, although the close agreement of the two water determinations, made as they were on samples containing different proportions of gangue, would indicate the correctness of the formula $2[R_2(OH)VO_4]+H_2O$.

Other specimens have since been received from the above named persons in which the earthy vanadate was associated sometimes with compact cerussite and galena in process of alteration. A dull reddish substance which constituted a part or even the whole of some lumps contained, besides silica, iron and some antimony in an oxidized condition, but carried little or no vanadium.

Professor F. A. Genth has already called attention* to the occurrence of vanadinite and probably of descloizite in the Bald Mountain mine, Beaverhead County, Montana. His specimens, however, showed the supposed descloizite as a pale brownish crystalline coating on yellow ferruginous quartz, whereas the present mineral shows no evidence of crystalline structure.

2. *Commercial Mine, Georgetown, Grant County, New Mexico.*

This is one of the most interesting occurrences of descloizite known, because of the extreme brilliancy of coloring of the mineral. The ore bodies in the Commercial mine, as well as in the adjoining MacGregor and Naiad Queen mines, occur in limestone immediately under an overlying slate, and appear to narrow in depth where certain eruptive dikes cut through the lime, as Mr. MacIntosh, foreman of the Commercial mine, informed me. The absence of the superintendents of the several mines and the very brief visit I was forced to make prevented obtaining more certain and detailed information.

* Proc. Am. Phil. Soc., xxiv, 38, 1887.

In places where the rock is most fractured and crushed the descloizite appears in greatest quantity and finest condition as an incrustation on quartz, often covering large surfaces, and in color varying from yellow through all shades of orange-red to deep reddish brown, the last named colors predominating. The black color so frequent in descloizite from Lake Valley, New Mexico, caused by a superficial coating or admixture of pyrolusite, is so far as my observation extended, wanting, hence specimens from Georgetown are likely to be much sought after for their showy appearance. A specimen in one of the banks at Silver City, New Mexico, taken from one of the Georgetown mines, resembled a stalactite in form. It was probably fully three feet in height by six to eight inches or more in diameter, and was deep reddish brown in color.

The incrustations are for the greater part distinctly crystalline and are generally made up of aggregates of more or less globular forms of a size ranging from microscopic to a diameter of one or two millimeters. Each of these is composed of a great number of apparently flat crystals, intergrown, and projecting sufficiently from the surface to give brilliant reflections when observed under the lens, and to the naked eye a frosted appearance where the globular growths are largest. The richest reddish brown color is always coincident with this development in size. The globular character changes frequently to acicular. In such cases the incrustation seems to have originally formed on bunches of radiating acicular, almost colorless, vanadinite, which frequently appears thus coating the quartz and running under the descloizite incrustations. Sometimes the vanadinite has entirely disappeared, and then there may be a hollow through the center of the descloizite needle.

The occurrence of vanadate of lead in the MacGregor mine at Georgetown has been noticed by Professor Genth (l. c., p. 38). The specific gravity of the mineral was not determined; the hardness is about 3·5; the color of the powder is orange-yellow. An analysis gave the following results after deducting 11·91 per cent of insoluble matter, almost entirely quartz.

		Molecular ratios.		
PbO	56·01	·2512		
CuO	1·05	·0132		
FeO	0·07	·0010	·4843	·4788	4·12
ZnO	17·73	·2189		
V_2O_5	20·44	·1119		
As_2O_5	0·94	·0041	·1178	·1162	1·00
P_2O_5	0·26	·0018		
H_2O	2·45	·1361	----	·1361	1·17
Cl	0·04	·0011			
SiO_2	1·01				
CaO	0·04				
MgO	0·03				
	100·07				

The third column of molecular ratios gives those values after allowing for admixed vanadinite calculated on the basis of the chlorine found. A further correction has probably to be made for an admixed soluble hydrous (zinc ?) silicate, which might make the ratio approximate more closely to 4 : 1 : 1.

3. *Lucky Cuss Mine, Tombstone, Cochise County, Arizona.*

Mr. W. F. Staunton, Superintendent of the Tombstone Mining and Milling Co., and Mr. Frank C. Earle, assayer at Tombstone, kindly placed at my disposal for examination specimens of a vanadium mineral the identity of which had not been established. It was found in the Lucky Cuss mine as an incrustation, sometimes half an inch thick, on quartz, showing more or less botryoidal surfaces of an indefinable dull greenish color. On a fractured surface the color is brown; the luster is resinous; the structure granular, only occasionally diverging fibrous; the hardness 3·5; the specific gravity of sample analyzed, containing a little impurity, 5·88 at 19° C.; color of powder lemon-yellow. Analysis gave the following results after deducting 0·67 per cent of insoluble matter.

			Molecular ratios.		
PbO	57·00	·2556			
CuO	11·21	·1412	·4485	·4385	3·93
FeO	trace.	----			
ZnO	4·19	·0517			
V_2O_5	19·79	·1084			
As_2O_5	1·10	·0048	·1145	·1115	1·00
P_2O_5	0·19	·0013			
H_2O	2·50	·1389	----	·1389	1·25
Cl	0·07	·0020			
SiO_2	0·80				
CaO	1·01				
MgO	0·04				
K_2O	0·10				
Na_2O	0·17				
CO_2	0·82				
	98·99				

The low total is probably owing to a loss of zinc during analysis. Calcite was present as an impurity, and as the CO_2 just suffices for the CaO and MgO these are rejected in considering the composition of the vanadate. The figures in the third column of molecular ratios are found by allowing for probably admixed vanadinite calculated from the chlorine found. In another specimen a qualitative test for chlorine indicated a greater admixture of vanadinite. As in the case of the descloizite from Georgetown, New Mexico, previously described, a further allowance has perhaps to be made for a soluble hydrous silicate. There can be no doubt that the general formula for the vanadate is that of descloizite.

In almost every respect this mineral resembles, so far as the published descriptions allow of judging, the descloizite of Penfield,* the cupro-descloizite of Rammelsberg,† and the ramirite of de Leon,‡ perhaps also the tritochorite of Frenzel,§ to the similarity of which with his variety of descloizite Penfield draws attention in his paper. Professor Genth's surmise (l. c., p. 39) of the specific identity of all these substances seems highly probable. Characteristic for the present variety is the greater replacement of the lead-zinc vanadate—true descloizite—by the isomorphous lead-copper vanadate, and the lessened tendency toward a fibrous structure, which in the other varieties described seems to be a decidedly pronounced feature. Possibly this last characteristic of the Tombstone mineral, if it be not accidental in view of the few specimens (three) examined, is a condition of the first.

According to Rammelsberg,‖ the lead-copper vanadate corresponding to the lead-zinc vanadate (descloizite) is mottramite or psittacinite, though it seems not improbable that it may be the chileite of Dana's Mineralogy. Domeyko's analyses,¶ which led Kenngott to ascribe the above name to the Chilian mineral, show a deficiency of 2·5 and 2·8 per cent, which may very well be V_2O_5. At all events, a recalculation of his analyses based on this assumption leads to a proportion for $PbO+CuO : V_2O_5 : H_2O$ of nearly 4 : 1 : 1.

In view of the well defined character of all these highly cupriferous varieties of descloizite it would be well to designate them once for all by some distinctive name. Tritochorite would have precedence if the substance to which that name has been given is really identical with the others, but Rammelsberg's cupro-descloizite is more appropriate as indicating at once the relationship to descloizite, and I would suggest that it be henceforth used for all cupriferous descloizites showing the physical characteristics of the mineral above described.

Note.—Since the foregoing was written there has appeared in the Bull. Soc. Franc. Min., Feb., 1889, p. 38, a paper by F. Pisani, in which he gives another analysis of the Mexican cupro-descloizite and discusses briefly the relations of various vanadates. The essential identity of all the above enumerated cupriferous lead-zinc vanadates, with the addition of another—schaffnerite—concerning which I have been unable to find any further reference in mineralogical literature, is therein upheld, and the suggestion of Penfield's regarding the possible identity of tritochorite and

* This Journal, III, xxvi, 361, 1883.
† Monatsb. Berl. Acad., 1883, 1215.
‡ La Ramirita, nueva espèce mineral, Mexico, 1885.
§ Tschermak's Min. and Petr. Mitth., iii, 506, 1880; iv, 97, 1881.
‖ Chemische Natur der Mineralien, p. 32.
¶ Ann. d. Mines, IV, xiv, 150, 1848; Phil. Mag., III, xxxiv, 395, 1849.

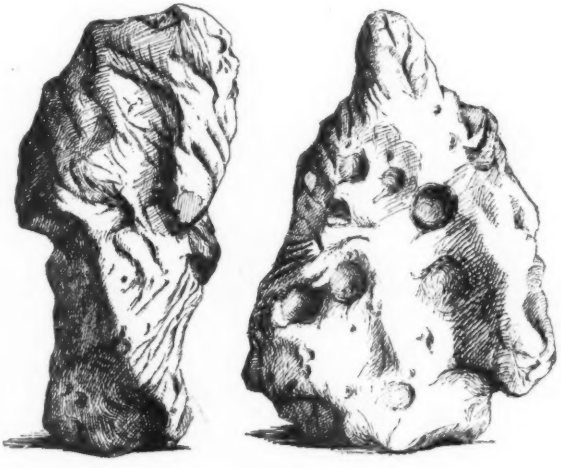
cupro-descloizite is confirmed by Frenzel himself, who is quoted as writing to Professor DesCloizeaux that he had not thought it necessary to consider as an essential constituent the two per cent of water which he had found in tritochorite.

Laboratory of the U. S. Geological Survey,
Washington, D. C., Feb. 9, 1889.

ART. XLV.—*A new Meteorite from Mexico;* by J. EDWARD WHITFIELD.

WHILE in Mexico during the summer of 1888, Prof. H. A. Ward, of Ward and Howell, Rochester, N. Y., obtained an undescribed mass of metoric iron weighing 33·0 kilos.

The meteorite was found on a peak of the Sierra de San Francisco, called La Bella Roca, in front of Santiago Papasquiaro in the state of Durango. The date of its discovery and the name of the finder are unknown.



The two greatest dimensions of the mass are $24{\cdot}13^{cm} \times 34{\cdot}92^{cm}$; an idea of the shape and general appearance may be had from the accompanying cut which shows what is supposed to be the front and back of the meteorite, at least during the latter part of its flight.

The composition of the metallic portion does not differ materially from that of other meteorite irons as the following analysis will show.

Fe	91·48
Ni	7·92
Co	0·22
P	0·21
S	0·21
C	0·06
	100·10

A feature of the meteorite is the presence of large, deep pittings on one side; these are a little greater in diameter just below than immediately at the surface and each one has a little substance left at the bottom, which evidently is the remains of what originally filled the cavities. I succeeded in breaking from the bottom of one pitting material sufficient to determine its nature. It proved to be troilite as the analysis will show.

NiS 2·13, FeS 85·27, Fe 9·37.

The exposed surface of the troilite was greatly decomposed; this portion gave by analysis the following figures.

NiS 2·07, FeS 37·51, Fe_2O_3 37·80, Moisture =19·85.

This decomposition gives grounds for the idea that the deep pittings were formed by the removal of troilite nodules, partly while the mass was hot and partly by the subsequent weathering.

There are nodules of troilite throughout the entire mass of the meteorite but none are removed, so as to form pittings, on any other part of the surface but the side which is supposed to have been the front.

The mass is deeply furrowed, as may be seen to some extent in the figure, and all the furrows tend away from the side containing the pittings.

Slices of the meteorite, when etched, show rather coarse Widmanstättian figures and also dark diagonal bands of troilite.

From the locality in which this meteorite was found it is but proper that it should be called "La Bella Roca."

I am indebted to Messrs. Ward and Howell for the material for examination and the privilege of description.

Chemical Laboratory, U. S. Geol. Survey,
Washington, D. C., March 3d, 1889.

ART. XLVI.—*Contributions to the Petrography of the Sandwich Islands;* by EDWARD S. DANA. With Plate XIV.

THE rock specimens, the results of whose study are detailed in the following pages, were in part collected by Professor James D. Dana on his trip to the Sandwich Islands in August, 1887, and the remainder by the Rev. E. P. Baker of Hilo in 1888. The first series includes about thirty specimens from Kilauea, a third of them from the projectile deposits on its borders; several from other points in Hawaii; about a dozen specimens from the island of Maui, chiefly from the extinct crater of Haleakala; and finally an equal number from different points on the island of Oahu. The special localities are mentioned beyond. The second series of specimens are all from Hawaii, and chiefly from Mokuaweoweo, the summit crater of Mauna Loa. There are also a few specimens from Makaopuhi and Nanawale on Hawaii, points which belong to the Kilauea region.

For our present knowledge of Hawaiian lavas we are indebted in the first place to the general descriptions of J. D. Dana in the Geology of the Exploring Expedition (1849), and W. T. Brigham in his Notes* on the Volcanoes of the Hawaiian Islands (1868); also C. E. Dutton (1884) and others. On the other hand, on the petrographical side, there have been published the microscopic study of basaltic glass of Hawaii, especially Pele's Hair, by Krukenberg† in 1877; a paper by Cohen‡ devoted chiefly to the glassy basaltic lavas of Hawaii; brief descriptions of isolated specimens of nepheline basalts believed to have come from Oahu by Wichmann§ and by Rosenbusch;‖ finally a recent memoir by Silvestri¶ describing a series of ancient and modern lavas from Kilauea collected by Prof. Tacchini in 1883.

1. *Lavas of Mauna Loa and its summit crater, Mokuaweoweo.*

For the collection of lava specimens from the summit crater of Mauna Loa, the writer is indebted, as is stated above, to the Rev. E. P. Baker.** The collection is a large one and evidently

* Mem. Boston Soc. Nat. Hist., vol. i, pt. 3.

† Mikrographie der Glasbasalte von Hawaii, petrographische Untersuchung von C. F. W. Krukenberg, Tübingen, 1877.

‡ Jahrb. Min., vol. ii, 23, 1880.

§ Jahrb. Min., 172, 1875.

‖ Mass. Gesteine, 510, 1877.

¶ Bull. Com. Geol. d'Italia, xix, 128–143, 168–196, 1888.

** Mr. Baker's extended trip over Hawaii, which included, besides an exploration of the summit crater, a visit to the sources of several of the great lava streams, was undertaken in order to make the collections of rocks and gather facts with regard to the eruptions, and some extracts from his notes are published in this volume at p. 52. The results have proved to be of very great interest.

represents well the characteristic types of rocks. It numbers, exclusive of the "pumice" and scoria upwards of seventy specimens; of these about fifty have been subjected to microscopic study. In regard to the geographical distribution of the rocks with reference to their relative age but little can be said. A considerable part (Nos. 90–109) are from the talus within the southern crater of Mokuaweoweo against the neck between it and the central pit. (See the map in vol. xxxvi, plate II). A number of others (78–89) are from the eastern side of the central pit; and in the case of scattering specimens, the special source is mentioned more minutely beyond, when interest seems to attach to it.

In general it may be said that all the specimens in hand from Mauna Loa belong to the same class of basaltic lavas, although they vary widely: in color from dark gray to light gray or dull brick-red; in structure from compact to highly cellular or vesicular; from those of uniform grain to those which are prominently porphyritic with chrysolite or feldspar; and in composition from the very highly chrysolitic kinds to the feldspathic or augitic forms with little or no chrysolite. Specimens of pumice-like scoria are largely represented in the collection.

The specimens may be divided pretty sharply into two groups, besides which there are several other types more or less distinct from these.

Clinkstone-like basalt.—The first of these doubtless includes the rock which former observers have spoken of as resembling phonolite. Macroscopically it has a uniform fine-grained texture, for the most part free from vesicles and apparently compact, though often found on closer examination to be minutely porous. The color varies from a dark bluish gray to light gray, and to dull brick-red or brown, the grayish kinds being the most common. The specific gravity varies from 2·82 to 3·00.* Many of these specimens, as taken from the talus between the central and southern craters, are in the form of thin slabs and their resemblance to clinkstone in the hand specimen, though not going beyond external aspect, is sufficiently close to explain their having been so named. As regards composition the rocks of this type are most strongly marked by the fact that the chrysolite, which is so common in large grains in the other specimens to be described, is absent or only sparingly present.

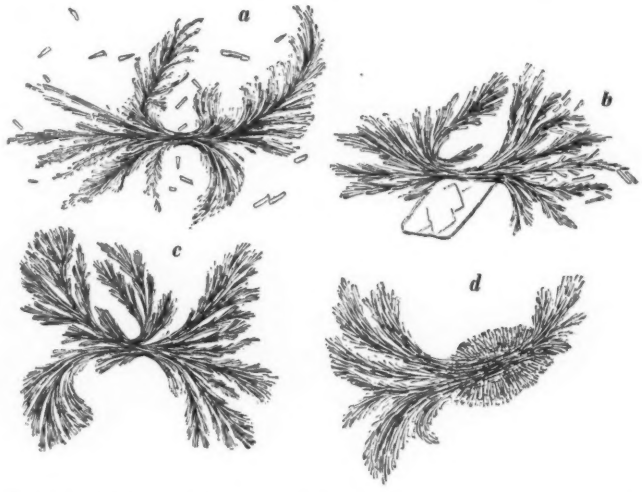
The microscopic characters of this group of fine-grained compact rocks are also such as readily to distinguish them from the other forms. In general they consist of augite and plagio-

* Some of the separate determinations on fragments freed from air by boiling are: 3·00, 2·94, 3·00, 2·87, 2·82, 3·00, 2·82.

clase, and titanic, or magnetic iron or both, prominent, but with little or no chrysolite. Their most interesting feature is the form taken by the augite, which is only exceptionally developed as an idiomorphic constituent, but on the other hand is not simply a formless substance filling the spaces between the feldspar. It is uniformly, though with varying degrees of distinctness, grouped in radiating forms, fan-shaped or feather-like, of great variety and beauty.

This structure is eminently characteristic of this group of rocks. It is shown best in a fine-grained purplish colored specimen (No. 97, G.=2·82). This is seen under the hand glass to be minutely porous though not properly vesicular, with minute slender red crystals (augite) projecting into the cavities. An occasional grain of chrysolite can be detected in the mass and cleavage sections of feldspar are also seen. Under the microscope it is made up of lath-shaped feldspar individuals and the beautiful groupings of augites, these set out in relief by the fine grains

1.



Feather-forms of augite; *a* (×35), *b* (×35), *c* (×50) from Mokuaweoweo, *d* (×70) from Kilauea.

of iron ore surrounding them. In the simplest cases the augite is bunched together in long parallel groups slightly diverging at the extremities; generally these branch off at various points into feather-like or dendritic forms, of such variety as to be

beyond description. Groups of these forms radiating from a center are common.*

The accompanying figure, 1, shows several of the more complex of these forms (*a*, *b* from this specimen) and gives a fair representation of this remarkable structure. Figure 2 gives the appearance of the entire field of the microscope, showing forms like the frost crystals occasionally seen on a stone pavement; this figure is simplified by the omission of some of the less defined parts.

Some of the simpler rosettes are made up of both feldspar and augite alike radiating from a common center; and frequently the extremities of the feather ends are feldspar individuals. Figure 3 gives a detailed drawing of part of one of

2.

Feather-augite in basalt from Mokuaweoweo. Magnified 60 times.

3.

Detailed drawing showing the feather-like grouping of augite and feldspar. Magnified 100 times.

the groups. It would seem that the feldspar was as usual first separated, and the augite as it crystallized out into these dendritic forms drew the feldspar needles into position with it. The two minerals are sometimes so intricately involved with each other that it requires close examination to separate them. In polarized light the distinction comes out more sharply.

* Mr. H. Hensoldt of New York has called the writer's attention to an augitic lava from Tahiti in which the pinkish, pleochroic augite is present in radiating groups of acicular crystals, often having a nucleus of chrysolite. The section is one of very exceptional beauty and interest, although the arrangement of the augite is hardly to be compared with that here described, since the individual crystals are sharp and geometrically grouped—after the manner of the tourmaline in luxullianite—which is in marked contrast to the feather forms of the Mauna Loa augite.

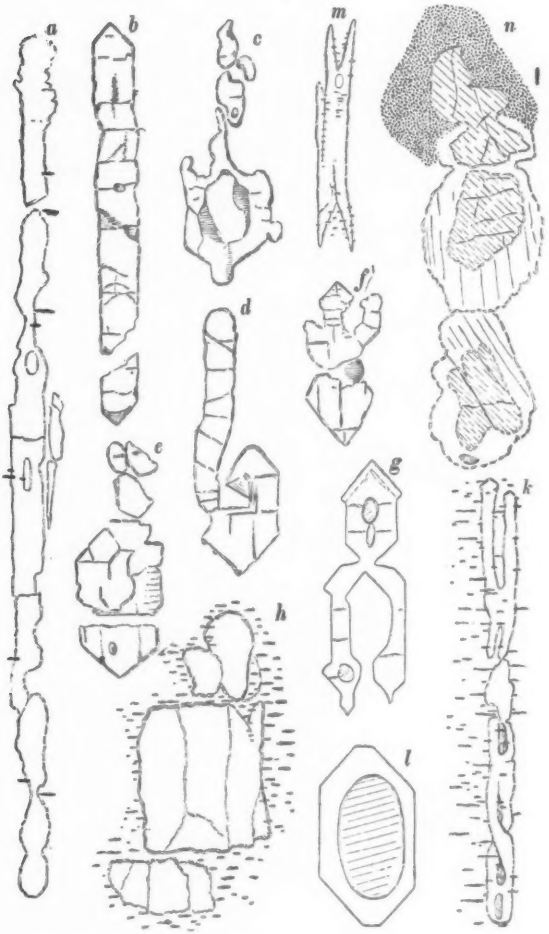
Occasionally the feldspar is present in larger forms; and more interesting to note is an occasional augite crystal (fig. 1, *b*) that evidently belongs to an earlier generation, and shows the distinct cleavage, and more or less also the crystalline outline of the species. The alteration to which this specimen, with others like it, has been subjected, and to which the red or purple color of the rock in the mass is due, has stained the iron red and reddened also the augite, although only exceptionally to such an extent as to make it opaque. The alteration spoken of may be simple weathering, although the occasional brick-red color rather suggests the action of hot water or steam; the feldspar remains perfectly clear and unchanged.

From the specimen described, which may be taken as the type, we pass to the coarser grained kinds on the one hand and to the very fine-grained on the other; both of these still retaining, however, the same general characters. A highly cellular specimen (74) with large vesicles, from the northwest brink of the crater, departs in general aspect most widely from the type; but, while relatively coarse-grained, it exhibits the same grouping though somewhat more rigid and geometrical, and shows even more clearly the mutual relations of the feldspar and augite. In the finer grained varieties (as 78) the augite sometimes predominates so largely that the whole becomes like a confused carpet pattern of interlacing arabesque forms, though here, when an individual form can be traced out, it has great beauty and perfection, branching and re-branching like some delicate forms of vegetation. Figure 1, *c* is an attempt to illustrate one of these forms, but it lacks the delicacy of the original. These forms consist almost exclusively of augite with very little feldspar. In another specimen of similar character a partial fluidal structure was noticed in the arrangement of the feldspar.

When the iron grains are only sparingly present and there has been no conspicuous alteration, the rock is of a light uniform gray, but the presence of iron in large amount makes it nearly black and obscures this structure; and when it and the augite are highly altered, the rock is a bright brick-red and in a section appears as a collection of nearly opaque red rosettes, the feldspar, however, still remaining clear. Glass is present occasionally, but usually in insignificant amounts, and for the most part it is nearly or quite absent. This feather-form of augite, which has been described, is not entirely confined to the clinkstone-like varieties of lava although eminently characteristic of them. It was occasionally noted more or less distinctly, in some other forms, especially the vesicular kinds to be mentioned later (p. 450) where it is seen in the minute second-generation augite which formed in the last process of consolidation. All the facts observed serve to connect its formation with rapid cooling.

Chrysolitic basalt.—The second group of rocks makes a very marked contrast with those just described. These are of coarse grain, often open-cellular, and very highly chryso-

4.



Chrysolite in part with orientated titanic iron; *a–f* (×55–60), from crystalline basalts of Mokuaweoweo. *g* (×75) from basaltic glass, Mokuaweoweo; *h* (×60) from Nanawale; *k* (×60) Kilauea; *l* (×100) crystal enclosing glass, Kilauea; *m* (×60), forked form, Maui; *n* (×60) portions of crystal enveloped by augite and clusters of magnetite grains, Maui.

litic; on this account the specific gravity is much higher, it varying from 3·00 to 3·20.* In many cases they have suffered some alteration which has given them a dull waxy surface, while the large grains of chrysolite are frequently iridescent and sometimes have an almost metallic luster. The color varies with the amount of iron oxidation from light gray to dull reddish gray or brown. The mineral constituents present are those of normal basalt; and most prominent among these is the chrysolite; in some specimens it must make up nearly half the mass of the rock; and in one case (102) probably more, this particular specimen having the unusual specific gravity of 3·20. The chrysolite was evidently early separated from the magma, and the changes of condition through which the lavas have passed is well shown in the irregularly corroded or occasional broken form of many of the crystals and grains. Even when there is a distinct crystalline outline, it is not a rare thing to find the crystal broken and the parts slightly separated. This is shown in the accompanying figures 4, *a* to *f*. Some of the corroded forms take very fantastic shapes. A novel and common feature of this chrysolite is the occurrence of very slender acicular forms. The length is often considerable, even when viewed macroscopically, in one case 2 to 3^{mm}, but in breadth they are often hardly more than a line, (note fig. 4, *a*.) This chrysolite shows the partial alteration alluded to in a broad rim of brown iron oxide; we can pass in the same slide from a crystal still preserving its transparency throughout, to those where only a string of chrysolite grains mark the position of the original individual, and from these to the cases where a narrow brown line of iron oxide alone is left; in a few cases (as 94) the chrysolite is stained bright red, showing that there has been oxidation of the iron without hydration.

The orientation of these peculiar rod-like forms, which are distinctly visible on a polished surface of the rock, is a matter of some interest. The fact that, in such a form as that of fig. 4, *b*, and others like it, the plane of the optic axes is transverse to the longitudinal direction and the bisectrix normal to the surface presented, shows that they are elongated in the direction of the vertical axis, the narrow dimension being that of the macrodiagonal. This chrysolite has often an unusually deep green color possibly connected with the partial alteration, and then shows distinct pleochroism with the absorption least in the direction of the vertical axis. It often shows spherical inclusions of a pale brown glass, sometimes arranged in parallel lines.

*Some of the separate determinations gave: 3·09, 3·18, 3·09, 3·04, 3·00, 3·20, 3·00.

The plagioclase feldspar is present in the ordinary forms, and shows no unusual features. The augite forms irregular grains crowded among the feldspars. Occasionally augite in larger more distinctly crystallized forms appears, evidently belonging to an earlier generation. This earlier augite shows the tendency, often observed, to cluster about the chrysolite grains. The titanic iron is not as a rule abundant, and for the most part appears in long slender rods often parallel among themselves over a limited area, and sometimes orientated by the chrysolite. In two or three of the specimens of this class the augite shows a tendency to assume the radiating form but this is the exception. Apatite is probably present in some sections, but only in small amount, and in most cases it was not detected. Glass is almost entirely absent from these rocks.

The occasional fractured character of the chrysolite has been spoken of; one specimen (90) shows this in an extreme degree, the chrysolite being separated here into many angular fragments for the most part showing no crystalline outline. The feldspar and augite individuals have also suffered in the same way and the ground mass has a curiously mottled microcrystalline structure suggestive of some porphyry. This specimen stands comparatively alone, although two or three others are of somewhat similar character.

Lavas with minute crystals of feldspar and augite in their cavities.—Allied to this second class of rocks just described, are a number of specimens which are interesting because of their remarkable crystalline structure. One of these (82) is a light gray rock with only occasional vesicles. It is, however, throughout open and porous with minute cavities into which project thin tabular crystals of feldspar seen distinctly with a strong hand-glass. A light yellowish augite is also observed, but the crystals are less distinct. Iridescent grains of chrysolite are scattered through the mass, and the fractured surface shows the same long lines of this mineral that are seen in the sections.

An interesting feature of this specimen and of others like it (including one very similar collected two or three hundred feet below the summit of the wall making the E.N.E. side of Kilauea, called Waldron's Ledge, also others from Makaopuhi) is the presence in cavities, of a mineral in very minute nearly spherical forms of a milk-white color. These are rather abundant through the mass of the rock, each little cavity containing one or two of them. They are so small (rarely more than ·2 or ·3^{mm} in diameter) that it is very difficult to determine their form, especially as the crystalline faces are dull and give almost no reflections. A hexagonal outline can usually be made out, and occasionally a triangular face through which the angle of another crystal sometimes projects, as if they were complex penetration twins, which the nearly spherical form also sug-

gests. Only one of these forms was detected in the thin sections, and the free side of this had a hexagonal outline, the whole being divided into sectors which alternately had like extinction, the surface of the sector being mottled in polarized light after the manner of some crystals showing anomalous optical double refraction. The fact that these little white spheres occur also on the inner glazed surface of the vesicles would seem to mark them of subsequent origin and hence probably zeolitic. Their form suggests a rhombohedral zeolite grouped like phacolite or the Australian herschelite. Two or three other zeolitic minerals were observed in isolated cases, but too sparingly and in too minute form to be satisfactorily identified.

In other specimens of this class (as 105, 107) the color is darkened because of slight alteration, the texture is coarser and the cavities larger. Here the clear glassy feldspar tablets are very distinct, and augite crystals, red or brown on the surface and opaque, also project into the cavities. Octahedrons of magnetite are often seen implanted upon the augite needles, and broad plates of titanic iron, with rhombohedral planes on the edges, sometimes attain a relatively large size. The feldspar tablets were here large enough to allow of their being separated and examined optically. In form they are either rhombic or acute triangular in outline, being bounded by the planes c (001) and y ($\bar{2}01$) or c and x ($\bar{1}01$), with the prisms very small when present at all. They can often be seen to be twins in accordance with the usual albite law. The extinction on the clinopinacoid made an angle of -14 to $-15°$ with the basal edge, which conforms to typical labradorite, as might have been anticipated. These highly crystalline specimens are also much like some of those collected from ejected masses about Kilauea, and they may here have had a similar origin.

All the specimens that have been thus far described were obtained with a single exception (No. 74 already located) either from the talus in the southern crater against the wall of the neck that joins it with the central pit, or else from the east side of the interior of central Mokuaweoweo. Nothing can be said in regard to the relations in place of the two types of basalt which have been described and which occur together at the points mentioned.

Other varieties of the lavas.—A number of the specimens cannot be classed in either of these two groups. They are light gray in color, not vesicular, and sparingly provided with chrysolite, if it is present at all, and characterized by a very uniform granular mixture of augite and plagioclase. A specimen taken from a vein in the western wall belongs here, also another stated to have come from the highest point on the edge of the crater. Still another specimen from the north brink is similar, but is porphyritic with patches of a glassy plagioclase.

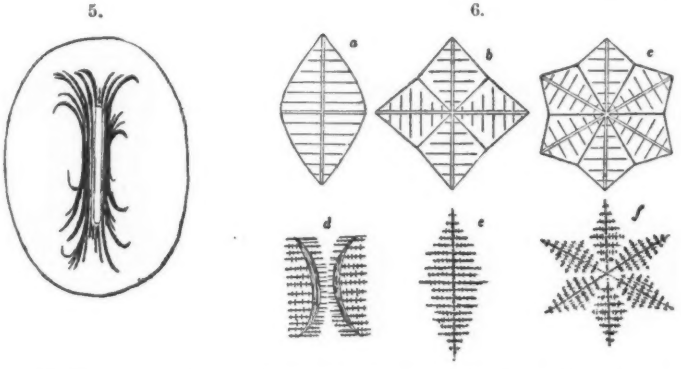
Another group of specimens, differing in aspect widely from those described, although not essentially so in composition, are the highly vesicular kinds, sometimes coarsely vesicular and again with very minute cavities. They have for the most part a common character. Large grains of chrysolite are usually present, often very large in comparison with the size of the vesicles themselves, and with these also are sometimes large crystals of augite and feldspar, often grouped together. The ground-mass filling up the space between these first separated constituents is a dark fine-grained mass of plagioclase and augite with minute grains of iron sometimes so abundant as to render the whole nearly black and opaque. The augite sometimes shows a tendency to group itself in the radiating forms already described. A fluidal arrangement of the feldspar is the exception though occasionally observed in indistinct form. Only in rare cases is the whole mass of the rock made up of this fine-grained mass without the large crystals. A specimen from the source of the 1843 flow belongs here.

A specimen (76) which is described as the "ordinary ancient lava of the eastern brink of the crater" is a dark colored, coarsely vesicular rock (G.=3·00), with chrysolite abundant in large grains, and augite and feldspar also in large individuals, the amount of the fine-grained dark base of later formation is relatively small and the augite is somewhat radiated. A peculiar feature of the section is the inclusion by the augite of large plagioclase individuals not regularly orientated and giving the whole augite a peculiar mottled appearance.

Specimens of glass.—The Mauna Loa collection includes a large number of specimens of the scoria, many pumice-like specimens, some of them of extreme lightness and also specimens of glass. Several of the glassy kinds were examined microscopically. One of them (103) was a dense black compact mass uniformly glassy on one side, but on the other largely devitrified; the smooth surface of the glass was roughened by minute projections due to the chrysolite crystals. Its specific gravity is 2·91. Under the microscope the glass had a uniform brown color, and amorphous character, except for numerous minute doubly refracting points scattered through it. Here and there were clusters of small chrysolite crystals, having sharp outlines and perfectly clear except for occasional inclusions of the glass and minute black iron crystals.

A section cut transversely showed with great beauty the gradual transition from the amorphous glass to the largely devitrified lava. The pale yellow-brown glass of the border contained here and there elongated microlites, of dark brown color due to the glass immediately surrounding them, and also minute crystallites like those described below. In the inter-

mediate zone the microlites were more numerous and were surrounded by a brown oval aureole of somewhat deeper color than the rest of the glass, this having a beautiful spherulitic structure in polarized light. The nucleus was sometimes



5. Feldspar microlite surrounded by dark filaments within an oval of brown glass (×90).
6. Crystallites of various forms (×160). All from basaltic glass, Mokuaweoweo.

transparent (feldspar) and about this were curious dark brown processes thrown off in curved lines (see fig. 5). The highly devitrified portion consisted of a nearly continuous mass of dark brown spherulites and crowded among them numbers of whitish nearly opaque crystallites. Many of the spherulites have a distinct nucleus of chrysolite or feldspar, and sometimes there is a medusa-like mass of dark brown bands radiating out from the nucleus.

The crystallites (see fig. 6) have sometimes a simple oval form with a faintly indicated structure transverse to the longitudinal axis; there are also compound forms with axes crossing at 90°, making a four-rayed star (*b*), or at 60° and these last when repeated making a regular six-rayed star (*c*). Rarely these forms are resolved into a delicate skeleton form of the types indicated (*d*, *e*, *f*) and of many other less regular shapes. Similar forms of "crystalloids" are figured by Vogelsang in plate VII of his work, "Die Krystalliten."

Chrysolite is distributed through the section in isolated crystals or in clusters. These crystals often enclose a considerable amount of the brown glass, and while sharp in outline have sometimes peculiar forms (fig. 4, *g*) which are interesting in connection with the corroded forms met with in the highly crystalline basalts which have already been described. Feldspar is present in the more highly devitrified portion; augite not

distinctly except as some of the microlites are to be referred to it.

Another specimen was lithoidal in character and showed throughout a distinct spherulitic structure. The nearly opaque spherulitic ground-mass contained many light brown transparent spherulites, and grains of chrysolite were scattered through as in the other.

Lava streams from Mauna Loa.—A considerable number of specimens are at hand from the streams of Mauna Loa of different dates, and taken from points at various altitudes. For the most part they are simply the surface scoriaceous portions and consequently without distinctive features. The flows of 1852, 1855–56, 1859 are thus represented. There are also specimens of the normal crystallized lavas of the stream, 1881, at Hilo; of that of 1843 taken from near its source which has been already alluded to, and of 1868, 1880–81, 1882 and 1887. These are all dark colored chrysolitic lavas, vesicular in a high degree, especially that from near Hilo (1881) and their characters are those of the vesicular forms spoken of on page 450. The specimens of the flows of 1868 are to be mentioned as particularly rich in chrysolite.

2. *Lava Stalactites from caves in the Mt. Loa lava streams.*

Perhaps the most interesting and remarkable formations connected with the lava flows from Mauna Loa are the delicate stalactites and stalagmites of lava which ornament the caverns. The specimens in the collection are mostly from a cavern in the lava stream of 1881, near Hilo, as described on page 109 of the last volume of this Journal. Figures of some of the forms of similar stalactites from the caverns of Kilauea are given by Brigham as more particularly mentioned later. They are of so great interest as to demand a minute description.

According to the accounts given, the flowing lava stream, crusted over at the surface, leaves behind it, when the molten material has flowed by, long caverns usually eight or ten feet in height, having a roof of one to three or more feet in thickness and a floor of the solidified lava. In the caverns are found hanging from the roof the slender lava stalactites. In the Hilo cavern they were from a few inches to twenty or thirty in length, and in some places only six to eight inches apart. The diameter, which seems to have been determined by the size of the drop of the liquid material, does not vary much, being usually about a quarter of an inch. Beneath the stalactites, from the floor below, rise the clustered groups of the stalagmites. These delicate forms are so fragile that they hardly bear transportation, and it is consequently difficult to preserve the longer specimens in their original form.

Through the kindness of Mr. Baker, the writer has received an admirable series of them, part of which are shown, one-third of the natural size, in the accompanying plate. These specimens were collected with great care and skilfully packed in moss and although fractured at many points when they arrived in New Haven, and thus divided into sections an inch or two in length, it was found possible to cement them together in their original positions.*

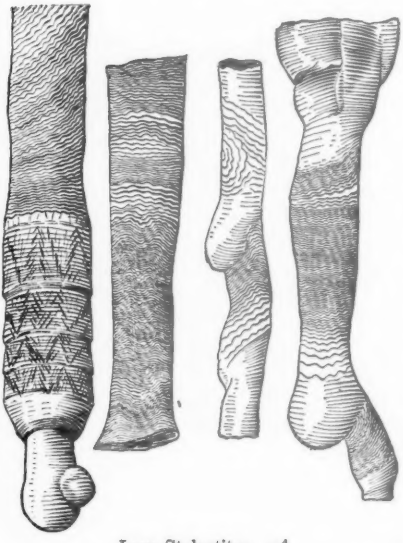
The general aspect of the stalactites and stalagmites is so well shown in the series of figures on plate XIV that but little description is needed. It will be noticed that while some are straight and nearly uniform, others are curiously gnarled and knotted, especially near their lower extremities. The end has often a little process thrown off at right angles, a little hook, or a close spiral of two or three turns often tangled or knotted together. The simple rods are usually round, not often flattened except when there is a sudden change in direction, when they may be pinched together like a glass tube bent when hot. The surface is exquisitely ornamented with most delicate markings. The stalagmites, formed by the droppings from above, are intricate clusters or piles of simple drops several inches in height as well represented in figures *a* and *b* on the plate.

The exterior of the stalactites has usually a more or less bright metallic luster, and, though sometimes dull and fine granular, the surface often reflects the light brilliantly from a multitude of crystalline facets; these sometimes separate into distinct scales, shown to be largely hematite by their reddish streak, though magnetite is also present. Minute rounded crystals, apparently also of hematite, are sprinkled often thickly over the surface. Sometimes the metallic covering is very thin, or is not continuous, forming patches on a brown surface. Occasionally at the ends it is altogether absent, and the exterior is thus brown and glassy in aspect, but still retains the polyhedral crystalline aspect; this glass-like crust polarizes light and is probably augite. Over portions of the rods—and in the case of the straight uniform ones (see the plate) over the whole length—the surface is transversely ribbed or corded in the most delicate manner. The beauty and perfection of these little ripplemarks, as seen under a hand-glass, are beyond description or adequate representation. They are parallel and symmetrical for a limited distance, but vary in fineness and form with every change in direction of the stalactite itself. Their flow is especially varied about each little projecting knob.

* For this skillful work as well as for the drawing of the plate, and of figs. 1–4 and 7, the writer is indebted to Dr. E. H. Barbour, recently of Yale University.

Figure 7 will give some idea of the transverse markings, but details of the structure can hardly be reproduced.

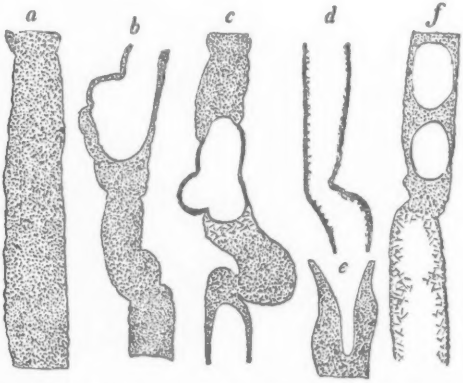
7.



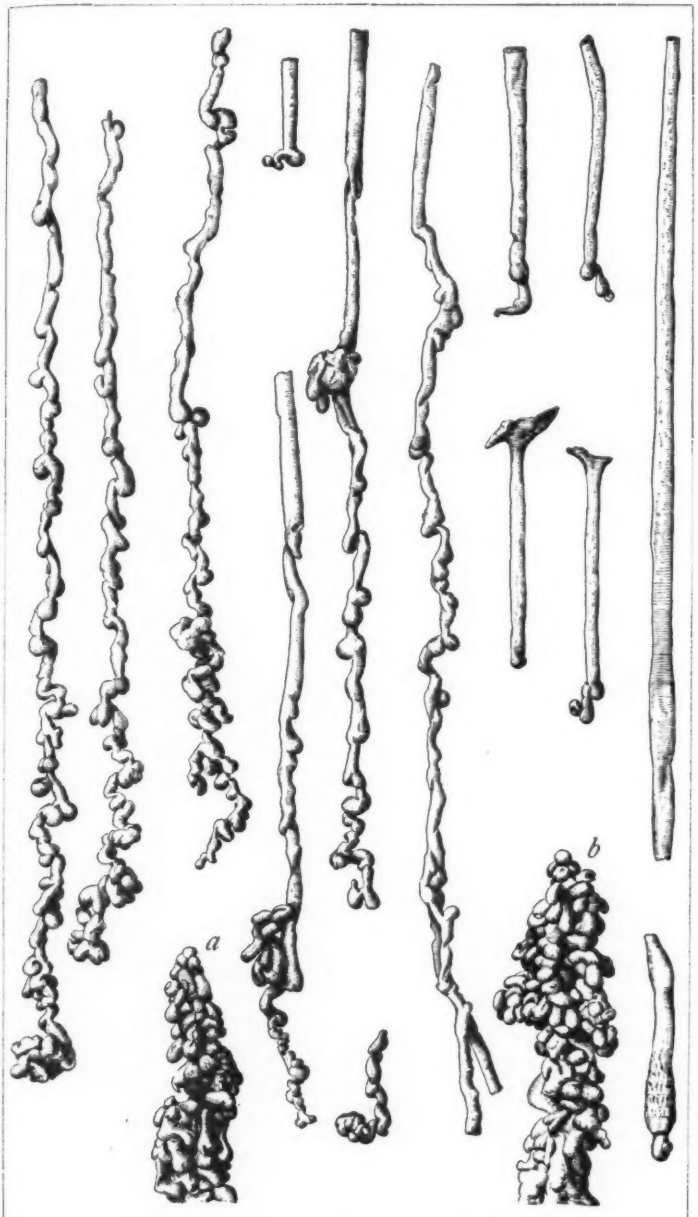
Lava Stalactites, $\times \frac{1}{3}$.

The straighter portions of the stalactites are often solid throughout, though here and there they are hollow and consist of a mere shell; often portions that are perfectly solid alternate with the cellular parts, or the solid parts contain a series of large vesicles. Figure 8 gives longitudinal cross sections through a number of typical forms. In *f*, the lower cavity was thickly lined with crystals chiefly of feldspar. The exterior crust is seen in the cross section under the microscope to be very thin, and next to it comes usually a narrow, but not always continuous, band of augite with occasional iron crystals. The solid parts contain within very slender lath-shaped

8.



Longitudinal sections of lava stalactites in outline ($\times \frac{1}{4}$) showing open and solid portions, *a* solid and *d* open throughout, *d* with crystalline lining; the lower part of *f* is thickly lined with crystals, chiefly feldspar.



STALACTITES FROM LAVA CAVERNS NEAR HILO ($\frac{1}{2}$).

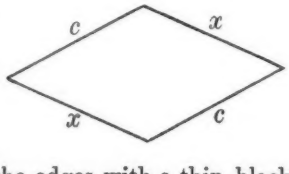
feldspars of a considerable relative length, often from $\frac{1}{4}$ to $\frac{1}{8}$ of the diameter of the stalactite, as seen in a longitudinal section. In one case they showed a marked tendency to parallelism with the axis of the stalactite, but in other cases this was less distinct. A partial concentric arrangement as seen in a transverse section was also noted. The feldspars often have black longitudinal inclusions probably of magnetite, and their cross sections, square or rectangular in outline, then have a large black center of the same form. A rather deeply colored greenish yellow augite, somewhat pleochroic, is packed in among the feldspars, and occasionally shows sharp crystalline outlines. There are also numerous grains and octahedrons of magnetite, and throughout a multitude of beautiful dendritic forms branching at angles of 90° or of 60°. This is one of the most marked characters of the sections. The areas, where these iron dendrites are crowded together, are less distinctly individualized, but no glass was noted. Chrysolite is also absent. Figures 9, *a* and *b* will convey some idea of the appearance of the longitudinal and transverse sections, though the relative amount of feldspar and augite is rather too small. The fact that the structure is throughout coarsely crystalline with the normal constituents of the basalt—except the chrysolite—is an important point.

9.

Sections of lava-stalactites (×3), *a* longitudinal; *b* transverse.

The occasional cavities or open spaces in the solid parts of the stalactite are often beautifully lined with large rhombic tables of feldspar, perfectly clear, and so excessively thin as to suggest scales of mica; also dark needles of augite, often curved and wire-like, and octahedrons of magnetite. (See 8, *f*.) The feldspar plates have mostly the form of a symmetrical lozenge (fig. 10), with angles of 128° and 52°; one side is shown by the cleavage to be bounded by the basal plane, the other by the dome x ($\bar{1}01$). The extinction makes an angle of $-7°$ to $-9°$ with the basal edge which conforms to that of andesine, that is a plagioclase somewhat more acidic than that determined in the rock mass. These feldspar plates are often marked on the edges with a thin black scale, presumably magnetite, with numerous minute circular open spaces containing many black points as if the whole

10.



were formed by the drying of little bubbles. The augite crystals are often rough and black with magnetite.

Where there are vesicular cavities, often filling the whole interior of the tube, these are lined with a comparatively smooth, shining web of feldspar plates and clusters of brown augite crystals, or of augite needles alone, woven together like basket work. The dull surfaces of magnetite octahedrons are scattered abundantly among the augite and feldspar. The large quantity of magnetite is shown by the fact that the magnet picks up many of the fragments of the stalactites, even when quite large. The specific gravity of fragments of the solid portion of a stalactite was found to be 2·98.

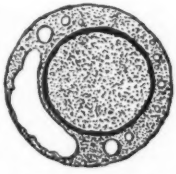
The explanation of the process by which these unique volcanic icicles have been formed is not easy to give. It is clear that further study, on the spot, of their occurrence and the circumstances of their growth is called for. It seems at first most easy to think of them as made by the rather rapid dripping of the semi-viscid lava from the roof. The evidence at hand, however, shows pretty conclusively that they could not have been the result of simple direct fusion. The fact that they hang down, from the solid crust, while the stalagmites formed by the dripping from above rise from the solid floor beneath, seems to prove that they were formed after the molten lava had passed by and the temperature had fallen below the point of fusion. If made directly from molten material, they could hardly be so perfectly crystalline throughout as they have been shown to be; we should expect to find them more like the glassy spatterings from the blow-holes of Kilauea mentioned on a later page. Moreover, the sorting out of the material is further evidence on the same side: the crystalline shell of hematite and magnetite, with its lining of augite, and within the solid crystalline mass, or the clusters of beautiful crystals chiefly of feldspar. Still again, the question has been raised as to whether the flow of a viscid liquid like the molten lava could form drops so small as the size of the stalactites show must have been present.

The fact that the lava rods or tubes of the stalactites are of nearly uniform size throughout their length, although bunched and knotted together at frequent points as has been described, is an important one.* It separates them, as to mode of origin, from the stalactites of a limestone cavern which form in a more or less conical shape from the flow down over the exterior surface of the lime-bearing solution. It seems to require that

* A stalactite from a Kilauea cavern collected by Prof. J. D. Dana is of interest here, since it forms an exception to those that have been described. About the first formed stalactite, with its rather thick magnetite shell (fig. 11) has been formed a second, somewhat vesicular and nearly concentric with it. This stalactite has the exterior coating of gypsum crystals spoken of by Brigham.

the shell should have formed first and that these tubes should have lengthened by the material carried down within them, finally resulting in their becoming solid to a greater or less extent. This is confirmed by the fact that the parts seemingly most solid often prove to have at the center minute crystal-lined cavities. The lengthening by the addition of material at the point of attachment above, the only other method that can be suggested, is difficult to conceive of.

11.



Transverse section of lava stalactite from Kilauea (×2) showing first formed stalactite within.

As the facts at hand are inconsistent with the theory of a direct formation from the melted condition, we are forced to speculate as to the power of the highly heated water vapor known to be present in large quantities, to form them from the roof by a sort of process of aqueo-fusion. This is a subject about which we know too little at present to make speculation very profitable, and the author prefers to drop the discussion here, in the hope that further observations may throw important light upon the matter. The experiments of Fouqué and Lévy in regard to the formation of basalt, with their important results, pursued the method of simple igneous fusion, and though Delesse and Daubrée have discussed the rôle of water in the formation of basalt and basaltic minerals, their investigations hardly seem to apply very closely to the present case.*

The fact that these stalactites occur also in the caverns of Kilauea has already been mentioned. Brigham describes them at some length, and although it is hardly possible to accept all his statements literally, especially as to rate and conditions of growth, his remarks are quoted here at length (l. c., pp. 462, 463):

"A formation which always excites the curiosity of visitors to Kilauea is found in many of the caves in the floor of the crater which have been undisturbed for several years. At first glance the tubes which hang from the roof and the curiously formed droppings beneath these, seem to be of igneous origin. An examination *in situ* shows that this was not the case. The roof of these caves is about two feet thick and generally unbroken; the stalactites do not occur under cracks and indeed there is often no fresh lava over the surface. The formative process may be clearly seen as the tubes form from day to day; and I have caught the steel-gray deposit in the drops on the end of the tubes upon my finger and watched its solidification. Usually the tubes are straight cylinders from one to three-eighths of an inch in

* Meunier has described the formation of chrysolite and of chondrules of enstatite, resembling those of meteorites, by the action of steam at ordinary pressures, with silicon chloride upon the red hot metal, C. R., xciii, 737, 1881.

diameter and sometimes more than two feet long. The bore is almost never continuous, and while externally they are smooth, within a mass of stony cells of considerable size is presented. As long as these tubes grow downward in the quiet upper region of the cave they hang perpendicularly, but when they reach farther down the currents of air and steam blow the deposits to one side and the tube becomes distorted; it may even return on itself. The drip in the bottom forms much thicker and more irregular stalagmites as will be seen from the figure which represents three actual forms not occurring, however, in the same cave. Specimens have been found which exceed eight inches in diameter and these are usually low and flat topped. The more slender ones sometimes rise to a height of two feet; and so rapidly is the silica deposited that they seldom increase in diameter but are true acrogens, none of the suspended silica running down the sides. In one cave the growth of the stalactites was at about the rate of an inch a week but owing to the varying amount of water or steam the production is quite irregular. They are often coated with beautiful white crystals of gypsum, sometimes tipped with needle-like transparent crystals of the same mineral when the cave is high. The natives collect them with the upper open joint of a long bambu."

The following analysis of the solid stalactite, by John C. Jackson, is given by Brigham:

	SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O
G. = 2·9	51·9	13·4	15·5	0·8	9·6	4·8	3·0	1·1=100·1

3. *Lavas of Kilauea.*

The specimens in hand from the volcano of Kilauea, which have been examined microscopically, include four specimens (12, 16, 17, 18) of the recent lava from the bottom of the crater, six specimens of the older lavas, two (13, 15) from Waldron's ledge on the northeast side and four (14, 19, 20, 26) from the wall west of Halemaumau; finally a number (1–11) from the ejected masses on the borders of the crater, especially on the west side. There are also a number of glassy and scoriaceous kinds.

1. *The recent lavas.*—The specimens of the recent lavas were taken from the stony part of the layer below the inch or more of glassy crust. They are dark colored, vesicular basalts, containing chrysolite but not in very large amount. The irregular grains of chrysolite are often aggregated together with augite crystals and to a limited extent with the lath-shaped feldspars, these constituents obviously representing those which first separated from the magma. The mass of the solid portion of the rock is of uniform character, consisting of augite and feldspar with the interstices between them black with the crowded grains or plates of magnetic and titanic iron;

about the borders of the vesicles the iron is especially dense. It is very interesting to note that these specimens are the only ones among those from Kilauea which show distinctly the stellate feather-like forms of the augite and feldspar so characteristic of many of the Mauna Loa lavas (as shown in fig. 1, *d*, p. 443). The augite forms here are usually smaller, and less varied, but there is the same grouping in parallel bundles diverging off at the ends into dendritic forms. The association between the augite and feldspar is also very close, as if the crystallization of the two had been almost simultaneous. Thus the feldspar not only forms in some cases the outer extremities of the feather but sometimes also is a central rib flanked on both sides by the augite.

Occasionally the chrysolite appears in the long slender forms noted as common among the Mauna Loa lavas. One of these is shown in figure 4, *k*, which also exhibits the peculiar feature of many of these rocks—often noted in other regions*—the grouping of the titanic iron in parallel position about the chrysolite, normal to the vertical axis. An arrangement of the elongated forms of the titanic iron in parallel position over small areas is sometimes noted where there is no evident relation to the other constituents. Usually, however, the chrysolite is the controlling influence and the individual often bristles with these little iron rods about its whole outline as seen in the section. Although these specimens were taken from so near the glassy crust there is little or no glass shown in the thin section. A specimen from the bottom of the Little Beggar, the lowest part of Kilauea, shows very considerable alteration, the surface being covered and the vesicles filled with crystals of gypsum; the mass is rendered red and nearly opaque by the oxidation of the iron.

A specimen of partially devitrified glass shows the presence of spherulites, like those mentioned in similar specimens from Mauna Loa, increasing in number where the devitrification is most complete. Crystals of chrysolite and microlites of feldspar are also present in large numbers. Some curious specimens from the spatterings about a blow-hole exhibit a vesicular glass with crystals of chrysolite and aggregates of augite and feldspar. The chrysolite encloses large amounts of glass, often in curiously arranged symmetrical bands. One of the crystals is represented in fig. 4, *l*.

2. *The older lavas.*—Of the ancient Kilauea lavas, one specimen from Waldron's Ledge (13) is remarkable for its highly chrysolitic character, as its unusual density (G.=3·18) well shows. It is a grayish compact rock thickly sprinkled with greenish yellow chrysolite grains. Under the microscope the chrysolite is seen to be in large individuals, usually irregular

* Cf. Rosenbusch, Mass. Gesteine, p. 722, 1887.

grains, though also in indistinct crystals and occasional rod-like forms. These often contain abundant glass inclusions. The grains are often packed about with a poorly defined border of augite and it is in this zone particularly that the little rods of titanic iron are regularly orientated, standing out from the chrysolite in the manner already described. Besides this, it is a granular mixture of augite and plagioclase not showing any glass. The other specimen (15), from the foot of Waldron's Ledge, is a light-gray cellular rock, highly crystalline, the minute cavities lined by plates of feldspar and tables of titanic iron. It is much like some of the specimens described from Mauna Loa (p. 448), and with them is characterized by the same milk-white spherical mineral in the cavities, provisionally referred to phacolite.

The lavas from the west wall of Kilauea west of Halemaumau are all closely similar in character among themselves: they are dark-gray in color, vesicular, and contain a fair amount of chrysolite. The structure is throughout crystalline, rather coarsely granular, and the chrysolite is marked by its usual bristling border of titanic iron. One or two of these show something of the radiating augite forms.

3. *Ejected masses on the border of Kilauea.*—The specimens from the borders of Kilauea are supposed to have been ejected at an explosive eruption about a century since. The larger part of the masses are described by Professor J. D. Dana as being of a fine-grained, gray, slightly vesicular lava. Other specimens* are reddish or chocolate-colored, coarsely granular and highly crystalline. In the latter, the chrysolite is present in very large amount and has suffered from alteration, probably by the action of heated water vapors, so that the fractured surface is either dull-red and opaque or else slightly iridescent. The feldspar crystals are clear and glassy, and where there are cavities they often project in distinct transparent plates from the walls. The crystals have an angle of extinction of $-14°$ with the b/c edge, and hence conform to labradorite, like those of similar occurrence among the Mauna Loa specimens. Under the microscope the chrysolite is seen to be surrounded with a deep-red border, and the iron oxidation has penetrated into the mass of the crystal sometimes along broad fracture-lines, and more generally in a network of fine wavy lines giving it a peculiar feathery aspect. Not infrequently the oxidation has gone so far that the chrysolite is perfectly opaque and by reflected light is bright brick-red.

Specimens 6, 7, 9† are examples of the light-gray lavas but of peculiar characters. No. 9 is a light-gray rock conspicuous among all those under examination for its beautiful crystalline

* Here belong Nos. 3, 8 with G.=3·18, 10 with G.=3·15.

† For 6, G.=3·15; for 9, G.=3·10.

structure. It is very light and porous and in each little cavity there are groups of crystals of feldspar in the usual rhombic plates, with minute slender needles of a pale yellow augite iridescent on the surface, and thick tables of titanic iron showing large rhombohedral planes ($cr=56°$). These last have bright faces, often cavernous, and with a bluish steel-like tarnish. The augites are flattened parallel to the orthopinacoid, as shown by the parallel extinction and the oblique optic axis. Chrysolite is present in the mass of the rock but hardly appears in the sections.

No. 7 is a similar rock, but more compact except for parallel lines of cavities partially filled with black glass. No. 6 shows the same structure in part, but the mass of the specimen has a base of a very black glass with crystals of feldspar, augite, and broad plates of titanic iron running through it. In the large cavities the crystals of these minerals project out, though the surface of the cavity is lined with a glassy web. One of the sections under examination is cut across the junction and shows both the uniform fine-grained crystalline portion and the glassy part with its large enclosed crystals. A curious feature of the glass is the presence of a swarm of minute apatite needles running through it in every direction. These do not extend into the crystallized parts. Apatite usually appears as one of the very earliest secretions from the magma, and why it should be thus localized in these patches of glass while absent from the crystalline parts of the rock, it is difficult to explain. In general, apatite has been found to be a rare constituent of the Hawaiian lavas.

Two others of the specimens (4, 7) are gray compact rocks extremely fine-grained except for occasional chrysolite grains. No. 1 is peculiar in having small uniformly-distributed patches of a dark colored slightly opalescent glass, which is deep brown and nearly opaque in the thin section except as it is penetrated by apatite needles which here also are confined to it.

With the specimen from Kilauea proper belong those collected by Mr. Baker from Nanawale and Makaopuhi, the former chiefly remarkable for their chrysolitic character, the latter sparingly so. Several of the latter specimens are remarkable for that crystalline structure that has been several times remarked upon, and one of them contains the white zeolitic mineral.

Former observers have dwelt at length upon the features of the glassy forms of the lava and the presence of glass in the partly crystalline varieties. This is probably to be explained by the fact that the specimens which first present themselves to the collector on his visit to the interior of Kilauea are the superficial more or less scoriaceous or glassy forms which constitute merely a crust and do not represent the true character of the average lavas. The writer has found glass only a com-

paratively insignificant element in the normal rocks and *often wholly absent*, even from those of recent eruption.

4. *Relation between the rocks of the Summit crater of Mauna Loa and those of Kilauea.*

In general, the lavas of the summit crater and of Kilauea, so far as examined by the writer, are strikingly similar in character, all being augitic basalts, varying chiefly as regards the amount of chrysolite present. The clinkstone-like rock of Mokuaweoweo has not been observed at Kilauea; but the feathery grouping of augite and feldspar which characterizes it belongs to the recent Kilauea lavas as well. The darker colored vesicular basalts, which are highly chrysolitic and hence of high specific gravity, are alike from both craters. Writers on volcanoes have attempted to draw conclusions in regard to the distribution of the heavier and lighter lavas according to altitude, limiting the former to the lower levels. This is a natural inference on *a priori* grounds, but it does not rest on observation as the facts already stated sufficiently show. It is a striking fact in connection with the mechanics of volcanic eruptions that lavas of the heaviest character (3·15 and 3·20) should have been raised to an altitude of nearly 14,000 feet above sea-level.

The chemical composition* of the Kilauea lavas is well shown by the series of analyses (14 in number,) given by Silvestri, and also those—chiefly of glassy forms—given by Cohen.

Of these analyses, three by Silvestri, (A, B, C), and two by Cohen (D, E), are quoted here, viz:—

A. Recent vitreous basalt, fresh and unaltered.
B. Older basalt, also fresh;
C. Older basalt, much altered;
D. Compact basalt-obsidian;
E. Pele's Hair:

	A.	B.	C.	D.	E.
	G.=2·97	G.=3·01	G.=2·80	G.=2·75	G.=2·66
SiO_2	49·20	48·82	48·60	53·81	50·82
TiO_2	1·72	1·16	----	2·01	*undet.*
Al_2O_3	14·90	15·22	25·45	13·48	9·14
Fe_2O_3	4·51	5·72	17·55	3·02	7·33
FeO	12·75	9·65	1·20	7·39	7·03
MnO	0·28	0·67	*tr.*	*tr.*	0·38
CaO	9·20	10·40	2·20	10·34	11·63
MgO	3·90	4·55	0·98	6·46	7·22
Na_2O	1·96	2·10	1·38	3·23	1·02
K_2O	0·95	0·90		0·64	3·06
P_2O_5	0·42	*tr.*	*tr.*	----	----
H_2O	0·10	----	1·87	0·57	1·74
	99·89	99·19	99·23	100·95	99·37

*The remark made by Professor J. D. Dana must be repeated here that the early analyses published in the Geological Report of the U. S. Exploring Expedition, having been made for him by an inexperienced analyst, are entirely unreliable and should not be quoted.

Of other specimens from the island of Hawaii there are two specimens from Punaluu, one from the outside of a bomb and the other from an *a-a* flow. The interesting point about these is the strongly accentuated flow structure as shown in the feldspar microlites as they find their way around the occasional large crystals of chrysolite and augite—the fluidal character is as a rule entirely absent from the specimens before described, and in general is not so common in basic as in acidic lavas.

Specimens from western and northwestern Hawaii, Kawaihae and Mahukono are again more or less vesicular chrysolitic basalts. Of these rocks that from Kawaihae is the most noteworthy because of the large clusters of glassy feldspar crystals which give it a striking porphyritic aspect.

5. *Lavas of Maui.*

From the island of Maui about a dozen specimens have been subjected to microscopical examination, of which three were collected by Rev. S. E. Bishop. The most recent lavas of Haleakala are represented by three specimens, all somewhat scoriaceous. One of these is from the summit at an altitude of nearly 10,000 feet, the others from the bottom floor. They are all very highly chrysolitic, and of high specific gravity (G.=3·10). The similarity of the hand specimens is so great that they might almost have been taken from the same block. They are dark colored, very vesicular, and highly porphyritic with both chrysolite and augite. The large and well-formed crystals of augite often have a narrow external zone of deeper color (violet-brown) and are distinctly pleochroic. They are usually mottled with inclusions of glass or iron. The chrysolite shows but few inclusions. The ground mass is thickly sprinkled with iron grains making it nearly opaque; small triclinic feldspar needles and a secondary augite in minute form are seen. In these specimens the feldspar must make up but a very inconsiderable proportion of the whole. These recent chrysolitic basalts in Haleakala are much more porphyritic and otherwise quite different from the basalts of Mauna Loa and Kilauea.

More different still are several specimens of the older lavas. One of these (29) is from within the crater. It is a very fine-grained, dark bluish gray rock of uniform texture, perfectly fresh and showing but few minute cavities. It is a feldspathic rock presenting under the microscope a rather confused aggregation of feldspar and augite, the latter in minute grains, the whole thickly sprinkled with grains of iron. Chrysolite is occasionally noted in peculiar elongated forms, generally forked at both ends, and having a border of titanic iron grains as before noted (fig. 4, *m*). The most marked peculiarity is

the presence of minute scales of a dark brown mineral, probably biotite, which, however, is only present very sparingly.

Another interesting specimen (30) which was obtained from the top of Haleakala is a thin, almost schistose rock, light gray in color and presenting the same sort of an aggregation of feldspar and augite under the microscope. Chrysolite, however, is a prominent constituent especially in the hand specimen. There are also large elongated but usually ill-defined aggregates of magnetite grains marking the presence of original large individuals, biotite or hornblende, which have been re-absorbed into the magma. Occasional remnants of the original mineral are noted but in very small amount. Another curious feature of this rock is the presence of a zone of augite about the grains of chrysolite. One case of this is illustrated by fig. 4, *n*. The chrysolite crystal though separated into different parts has throughout the same optical orientation as indicated by the shading, while that of the augite varies from grain to grain. The mantle of magnetite grains about the upper end of the chrysolite seems to represent the remains of the augite which has disappeared. This re-absorption of augite is not commonly observed, but this case, and still more another one where of a single augite crystal alone a large part has disappeared in this way, places the matter above doubt. This zonal arrangement of the augite about the chrysolite has been noted by other observers in a number of cases.*

The structure and composition of both these last mentioned rocks suggest that they should perhaps be classed among the augite-andesites rather than the basalts. To decide this point we have the silica determinations, for which I am indebted to Mr. Henry L. Wheeler of the Sheffield Scientific School. He found in the first (No. 29) 48·42 p. c. SiO_2, and in the other 50·44 p. c., which conform to that of normal basalt.

The remaining specimen from the top of Haleakala is a dark gray, almost black, rock of the finest grain, very compact and breaking with a conchoidal fracture. It is characterized by the large amount of iron in minute grains very thickly distributed, so as to make the section nearly opaque unless extremely thin. The feldspar microlites are the most prominent constituent, and these show a rather distinct fluidal arrangement. The two specimens from Paia on Maui are much like those from Haleakala just mentioned, especially No. 29, and like it they bear the same resemblance to andesite. A curious point about them, is their readiness to alter, the exposed surfaces passing into a soft earthy mass of a light brown color.

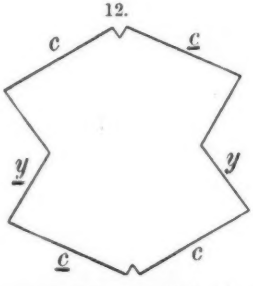
The specimens from Western Maui, collected by Rev. S. E. Bishop, are rocks of peculiar and interesting character. Mr.

*See F. D. Adams, Amer. Naturalist, 1087, 1885, G. H. Williams, this Journal, xxxi, 35, 1886.

Bishop says that they are "crusts and soft interiors of the same formation (apparently flowing lava) found on Launiupoko hill, 3 miles S. of Lahaina. A precisely similar formation occupies the front of Mt. Ball, 2½ miles above Lahaina. The crusts are often rolled under the gray, soft material. Many crusts of grotesque form lie about, from which the softer part has been washed away. Many portions of the gray, soft mass are of great thickness. Much building stone has been hewn from it. It presents no appearances of being the result of any decay, being compact and of uniform texture, except the hard crusts, many of which are crumpled up as if in flowing, like pahoehoe."

One of the specimens (28) is a whitish gray compact rock, whose surface is worn out into a series of deep holes between projecting ridges nearly one inch in height. The texture, though appearing closely compact at first sight, is seen by the glass to be minutely porous, and the surface is speckled with very small rusty spots. Under the microscope it is seen to consist almost exclusively of plagioclase, here and there porphyritically developed; there are also the remnants of a bright green pleochroic mineral present in traces only and obviously the original mineral whose disappearance has left the rusty spots; it seems to be hornblende. A little biotite is also present. Iron is scattered through the mass rather sparingly in minute grains; no augite was noted. Another specimen shows the transition from the firm rock to a soft chalky condition powdering under the fingers. The section is very like the other just described, though the feldspar is much clouded and an occasional red crystal of chrysolite is noted.

A third specimen (32) is a flake from a large bowlder (8×5×4 feet) found one mile S. W. of the summit of Mt. Ball. Mr. Bishop remarks that, in the eroded cliff, bowlders occur cemented by mud, being ejectamenta from Mt. Ball. The specimen is finely schistose and so soft and friable as to separate easily into thin silvery scales, and by handling it is soon reduced to a fine powder. Microscopic examination shows it to be very nearly the same in material with the others, but having a distinctly fragmental appearance. There is more chrysolite present in small broken fragments of crystals; there is also a little brown biotite in scales. The mass is made up of penetration twins of plagioclase according to the Carlsbad law mostly arranged parallel to



the brachypinacoid and hence showing no other kind of twinning. The form of one of these groups is shown in fig. 12. The cleavage marks the position of the basal plane and the angle of the section (about 80°) shows that it is bounded by the planes *c* (001) and *y* (201). The extinction makes an angle of a few degrees with the basal edge, varying + or − with a slight change in the direction of the section. This optical character and the further fact that the acute bisectrix is nearly normal to the brachypinacoid would make the feldspar an oligoclase. Occasional feldspar individuals are cut more nearly parallel to the basal plane and have the usual elongated form, and show the twinning like the other specimen, but as a rule they all lie nearly parallel to the brachypinacoid. The amount of silica present, as determined by Mr. Wheeler, is 61·63 p. c., which corresponds to the microscopic determination. This remarkable feldspathic andesite is a totally different rock from any other which has been as yet obtained from the islands, and the writer hopes to be in the position later to give a more minute account of its occurrence and composition.

5. *Lavas of Oahu.*

Of the specimens in hand from the island of Oahu, six (33, 36, 40, 41, 44, 45) are from the Kaliuwaa valley, near Punaluu on the north side of the island; four (27, 38, 39, 43) are from the Waialua plain; one (42) from a point just north of Kahuku Bluff; another (37) from a gulch beyond Monolua, 4 miles west of Honolulu; and, finally, there are a number of specimens of the tufa from the Punchbowl near Honolulu. Among these specimens, two are forms of highly chrysolitic basalts; these are the specimens from Kahuku Bluff and one of those from near Waialua. In the first of these (42) the chrysolite makes up probably two-thirds of the mass of the rock; it is present in distinct isolated crystals, having the characteristic form, each crystal having a rather broad, rusty border, though the interior is for the most part clear and unchanged. The chrysolite incloses grains of iron, but very little glass. The ground mass is a fine-grained mixture of augite and plagioclase with considerable iron, the augite being the more prominent constituent.

In the specimen from Waialua (43) the chrysolite is also prominent; its specific gravity is 3·06. With the chrysolite, the augite and feldspar also occur in large individuals besides being present in the base. The feldspar here contains dark-colored glassy inclusions in large numbers arranged parallel to the vertical axis. The base is a confused mixture of dirty brown augite and feldspar, with iron in considerable amount. The specimen (33) from a dike in the upper part of the Kal-

iuwaa Valley is a very compact, nearly black basalt, unusual in showing occasional grains of pyrite. The feldspar is fresh, but the augite is more or less altered and its place taken by a serpentinous substance, while occasional cavities are filled with a light colored radiating zeolitic mineral showing feeble double refraction. Besides the usual magnetic iron, which is scattered through in grains or octahedral crystals, there are also curious aggregations of iron ore in very slender rod-like forms, sometimes crossing each other at right angles, but usually matted together with a confusedly reticulated structure, sometimes forming nearly opaque spherical aggregates. Specific gravity 2·90.

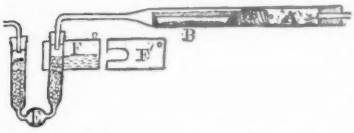
Chrysolite is present very sparingly in the remaining rocks, the hand specimen showing only here and there an isolated grain, and sometimes close search is needed to detect it. They are all light bluish gray basalts, with specific gravity ranging from 2·86 to 2·91. No very close study has been made of these specimens, but with a number of them their aspect, their highly felspathic character, and the microscopic structure, made it seem as if they might more properly belong to the andesites; a silica determination of one of them (36, G.=2·86) by Mr. Wheeler gave, however, only 50·55 p. c. SiO_2. Several of these rocks show more or less alteration, and in one of them (36) the occasional crystals of chrysolite have entirely passed into serpentine. For the most part they are highly crystalline, but one of the group (45, G.=2·88) is exceptional in showing numerous patches of a dark brown glass; this specimen is the most highly chrysolitic of the number, it being present in minute grains among the feldspar and augite, each grain having its orientated fringe of titanic iron. No nepheline basalt was detected among the specimens in hand.

Résumé.—The chief points brought out and discussed in the preceding pages are, the characters of the clinkstone-like basalt with its novel forms of feather-augite, and also of the heavy chrysolitic basalt, each from the summit crater; the general similarity between the lavas of Mauna Loa and of Kilauea and the crystalline character of both, even of the recent forms; the structure and origin of the stalactites in the caverns of the Mauna Loa lava stream, like those in the caverns of Kilauea, offering new problems in the formation of igneous rocks. It is shown further that the lavas in hand from Maui—with the exception of the andesite from the western part of the island—and also those from Oahu, belong to the basaltic type, though often approaching andesite in appearance; furthermore, that the lavas of Hawaii show extensive alteration but only so far as the iron oxidation is concerned, while some of those of Maui and Oahu, especially the latter, are much more profoundly changed.

ART. XLVII.—*The Determination of Water and Carbonic Acid in Natural and Artificial Salts;* by THOMAS M. CHATARD.

THE following method and apparatus having been used for the analysis of a large number of natural and artificial alkaline carbonates, have been found to give results which are satisfactory not only as to accuracy but also as to ease and rapidity.

A is a combustion tube drawn out and bent at a right angle, B is a platinum boat which contains the salt to be examined and rests upon the thin sheet of asbestos paper C used to prevent adhesion between the platinum and the glass when heated. D is a roll of asbestos paper wrapped with thin platinum wire, which fits loosely in the tube and prevents back-currents of air during the heating. The bent end of the combustion tube enters one limb of the U-tube E which is my own form and differs, as shown by the drawing, from those at present on the market, by having an especially large bulb at the bottom. The two limbs of the tube are filled with glass beads wet with strong sulphuric acid. Sufficient acid should be put in to fill the narrow tubes up to the bends, compelling the air-current to bubble through.



In using the apparatus the combustion tube is thoroughly heated and then allowed to cool, a current of perfectly dried air being continually passed through it and the part of the tube where the boat is to be placed being protected by a semi-cylindrical trough of sheet iron lined with asbestos paper. The U-tube, having been weighed, is now attached to the combustion tube as shown and the air current is regulated. The platinum boat, previously heated and then cooled in a desiccator, is weighed and about one gram of the salt put into it and spread evenly along the bottom; the salt should be very finely pulverized to prevent decrepitation. The boat with its contents should, after weighing, be at once inserted into the tube and the asbestos plug D which should have been highly heated and still be hot, shoved in close behind the boat.

The tube is now heated gradually beginning at the plug. As the water in such salts is driven out, in great part, at a low temperature the heating must be cautiously done and the air current must not be too slow else water may condense in the cold part of the tube back of the plug. When heating salts containing sodium bicarbonate, the regulation of the air current is the more difficult since the acid CO_2 of the bicarbonate

is set free simultaneously with the water, but upon this regulation and the gradual heating depends the success of the operation.

The water bath F, of which F′ is a top view, is now put into position, as shown, so that one limb of the U-tube fits into the curved recess in the side of the bath. A small alcohol lamp keeps the bath hot so that the water driven out of the salt may not condense in the upper part of the limb. By the use of this bath the time required for the operation is much shortened.

As soon as that part of the tube, which contains the boat, appears free from condensed water, it should be highly heated until all the moisture has disappeared from the drawn out portion. This will generally take from twenty minutes to half an hour; when completed, the water bath is removed and the apparatus allowed to cool, the air current being still kept up. As soon as the tube is cool, the U-tube is disconnected and the boat with its contents removed and placed in a small well stoppered glass tube which has been weighed.

The increase of weight of the U-tube gives the amount of water in the sample, while the weight of the small tube, containing the boat and the calcined salt, if subtracted from the sum of the weights of the tube, the boat and the salt taken, shows a loss which is the water plus the acid CO_2 of the bicarbonate. The calcined salt which should be sintered together but not fused can then be used either for a determination of the residual CO_2 or, as is preferred, dissolved and the alkali determined by standard sulphuric acid, methyl orange being used as the indicator, the same portion being then used for the Cl determination if chlorides are present.

Many attempts were made to collect and weigh the CO_2 driven off by heat, but it was found impracticable to do so without, at the same time, sacrificing the water determination. No matter how carefully the heat and air current are regulated, the CO_2 comes off too rapidly for proper absorption in a potash bulb and if the air current is too slow, water condenses back of the plug and this determination is too low.

When no attempt is made to absorb the CO_2, the results are very satisfactory. A specimen of Urao (Na_2CO_3, $NaHCO_3$+ $2H_2O$) from Owens Lake, Cal., gave the following results:

	Salt taken.	Loss of salt.	H_2O.	Difference=CO_2.
	1·0040	29·51	20·12	9·39
	1·0490	29·58	20·09	9·49
	1·1583	29·49	20·00	9·49
Average	1·0638	29·53	20·07	9·46

Three closely agreeing determinations of total CO_2 gave an average of 38·13 per cent; two determinations of the alkali

gave 40·28 per cent Na_2O equivalent to 28·58 per cent CO_2 required to make Na_2CO_3; 38·13−28·58=9·55 per cent CO_2 as the acid CO_2 of the bicarbonate present. Hence 0·09 per cent of this CO_2 was not driven off.

In another sample of Urao from same locality:

Salt taken.	Loss of salt.	H_2O.	Diff.=CO_2.	CO_2 in Res.	Sum CO_2.
1·1801	29·27	19·80	9·47	28·69	38·16
1·2297	29·35	19·83	9·52	28·64	38·16
1·2066	29·39	19·85	9·54	28·49	38·03
1·0880	29·26	19·80	9·46	28·67	38·13
1·1761	29·32	19·82	9·50	28·62	38·12

Two determinations total CO_2 gave 38·17 per cent and 38·22 per cent, average 38·19 per cent CO_2; two determinations of alkali gave 40·19 and 40·22 average 40·20 per cent Na_2O equivalent to 28·53 per cent CO_2. Hence as 28·62 per cent CO_2 was found in the residue we have 0·09 per cent acid CO_2 not driven off.

In a sample of Trommsdorff's C. P. sodium bicarbonate then was found:

Salt taken.	Loss of salt.	H_2O.	Diff.=CO_2.	CO_2 in Res.	Sum CO_2.
1·4265	36·68	10·91	25·77		
1·5995	36·81	10·90	25·91		
1·3200	36·71	10·91	25·80	26·25	52·05
1·3723	36·73	10·98	25·75	26·37	52·12
1·4296	36·73	10·92	25·81	26·31	52·09

Two determinations of total CO_2 gave average of 51·98 per cent; two determinations of alkali gave average of 36·88 per cent Na_2O equivalent to 26·17 per cent CO_2. Subtracting 26·17 from 26·31, average amount of CO_2 in residue, we have 0·14 per cent CO_2 not expelled by heating to sintering.

Comparing these amounts of excess of CO_2, retained by the residues of the ignition, with the weight of salt taken we have the following relations.

Sample.	No. of determinations.	Average wt. taken.	Average excess.	Relation of excess to weight.
Urao No. 1	3	1·0638	0·09	0·084
Urao No. 2	4	1·1761	0·09	0·077
Bicarbonate	4	1·4296	0·14	0·091
			Average	0·084

Hence we may say that if sodium bicarbonate, or a salt containing a large proportion of it, is heated till it sinters without fusing and is kept at that temperature for one hour, it still retains CO_2 in excess of the amount required to form mono-

carbonate with the alkali present; and that, for quantities of from 1 to 1·5 grams, this excess may be considered as one-tenth of one per cent of the salt taken.

For an analysis of sodium bicarbonate or baking soda, it is therefore sufficient to determine the loss by ignition, the H_2O, and the alkali in the ignited residue to obtain the total amount of CO_2 in the sample, adding to this amount an amount of CO_2 equal to 0·10 per cent of the weight of the samples taken. The method is much more rapid, far easier and quite as accurate as the distillation process, and may prove of value for technical purposes.

Art. XLVIII.—*Preliminary Note on the Absorption Spectra of Mixed Liquids;* by Arthur E. Bostwick.

In 1865 Prof. Melde, in experiments on the absorption spectra of mixed liquids,* proved, as he thought, that they were not formed by simple addition of the component spectra, but that the bands shifted, a large band of one liquid seeming, in general, to attract a small band of the other, and more strongly as the proportion of the former in the mixture was increased. Dr. Shuster, in discussing these observations,† shows that where a small band falls on the slope of a large one the effect of optical addition is to shift the apparent maximum of absorption, and concludes that "Prof. Melde . . . . would have observed exactly the same phenomena if he had put his two liquids in front of each other instead of mixing them together." The experiments herein described were undertaken to find out whether or not the effect observed by Melde was due to the cause alleged by Dr. Shuster; they appear to prove that while a small part was so due, the bands were shifted principally by a true action of one liquid on the other.

Melde's method consisted simply in observing the spectra of the liquids separately, and then that of their mixture. He made no attempt to observe that of one liquid in front of the other. The method of the writer was to observe the spectrum obtained by passing the light through both vessels, and then that obtained by mixing the liquids and pouring them again into the same vessels, thus sécuring exactly the same conditions except that of mixture. Common test tubes were first used, but an irregularity in results led to the discovery that the spectrum differed according as one liquid or the other was next the slit, each tube acting as a cylindrical lens. Cells

* Pogg. Ann., cxxiv and cxxvi.

† British Association Report on Spectroscopy for 1882.

with plane parallel glass faces one-quarter inch apart were therefore substituted and the spectrum found to be the same whichever liquid was next the slit. The position of the bands was measured by means of a tube bearing an illuminated slit the image of which moved over that of the spectrum as the tube was revolved around the same axis as the telescope and collimator. The amount of revolution was measured on a scale bearing a vernier reading directly to five minutes of arc, and by estimation to one minute. The cells being both in front of the spectroscope slit, a liquid in each, the image of the micrometer slit was fixed in the middle of the band whose deviation was to be measured. The liquids were then turned from the cells into a test tube, mixed there, and the mixture turned half into one cell and half into the other. The image of the slit was then seen to be no longer in the middle of the band, and to bring it there again the tube had to be revolved through from 1′ to 17′, according to the ratio of the liquids. But to avoid the effect of any unconscious bias on the part of the observer, the first band was observed with unmixed liquids, then the second, and then the two in the same order with mixed liquids, so that the observer did not know whether there were any movement, or in which direction it was, till he had fixed the micrometer and taken the reading.

The principal liquids used were those employed by Melde in his first experiments; namely, solutions in water of carmine with ammonia, bichromate of potassium, and ammoniacal sulphate of copper. The carmine and bichromate were tried first, and the former being kept at the same strength, the latter was diluted successively to $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, etc., of its first strength, which was that which just enabled the carmine bands to be seen. Dilution seemed to have no effect on the displacement of the band till the bichromate was very weak, when it fell off almost entirely. The mean of sixteen measurements, at various strengths of the bichromate, was 10′·9 displacement toward the blue end of the spectrum (absorbed by the bichromate) for the least refrangible carmine band, and that of ten measurements for the most refrangible was 8′·8. The measurements, which were all in the same direction, ranged in the first case from 19′ to 6′ and in the second from 14′ to 5′, a result due probably both to the difficulty of fixing the slit exactly in the middle of the band and to the variation in strength. An arc of 1′ in this place corresponds to a difference of wave-length of about ·4 millionths of a millimeter. The width of the bands was about 40′ so that the average displacement was about one-quarter of the width, an amount plainly evident without measurement.

Carmine and ammoniacal copper sulphate were now tried in like manner, and the bands were displaced toward the red,

that is, toward the part absorbed by the sulphate. The position of the bands with the carmine solution alone was measured frequently. The mean of from nine to twelve observations at different strengths gave: displacement due to simple superposition, 2·2′ and ·4′; additional displacement due to mixture, 5′ and 7·5′. The displacements due to mixture varied from ·1′ to 12′ for different strengths of the sulphate, and seemed in many cases to increase as the mixed liquids were allowed to stand. In some instances a flocculent precipitate was formed. As in the case of the carmine and bichromate, the displacement did not decrease gradually as the sulphate was diluted, but at a certain stage of dilution disappeared almost entirely. In the case of the copper sulphate and carmine this occurred when the ratio of the two substances by weight was about unity.

Fuchsin and aniline blue in alcohol were next tried, but the effect of mixture was the same as that of simple addition. With fuchsin and picric acid the fuchsin band either disappeared altogether on mixture or was much weakened and blurred at the edges. With a mixture of aniline blue and picric acid, the aniline band was much widened and perhaps shifted toward the blue. These substances were all tried by Prof. Melde. In the case of the aniline substances last tried, the writer's experiments indicate that Melde's results were due to simple addition, but in the case of the others an actual and very considerable motion of the narrow band toward the wide absorption area is indicated.

The writer hopes that he may be able rigorously to investigate the laws of this displacement at some future time, determining the substances which have on each other a real effect of the kind mentioned, and the dependence of the effect on the ratio of the substances, their temperature, and the time after mixture. With regard to the sudden diminution of the displacement at a certain stage of the dilution, it is easily understood if we suppose that the influence of the molecules, in producing the effect we view as a displacement of absorption bands, is proportional to a higher inverse power of their distances than the square, and that when those of one substance largely outnumber those of the other the more numerous are arranged in clusters about each of the others. Then dilution at first may have merely the effect of removing the outer members of these clusters, whose effect on the displacement is small, but when the inmost layer of the cluster is reached the case is different, and the effect of dilution shows itself at once. Our ignorance of the state of a physical molecule in solution prevents the direct test of this hypothesis by experiment.

Art. XLIX.—*Notes on Metallic Spectra;* by C. C. Hutchins.

In the work herein described an attempt has been made to determine the wave-length of several metallic lines with something of the precision with which wave-lengths of solar lines are known and tabulated.

It has been repeatedly pointed out that wave-lengths of metallic lines from the determinations of the best observers are liable to errors of one part in 3000 or 4000; while Rowland has given us the position of a long list of solar lines correct to one part in 500,000. It is too often forgotten that Thalen used a single bisulphide of carbon prism in his researches, and that consequently, his places can in no sense be considered standards of precision for the more powerful instruments of the present time.

The spectroscope employed in the present work has a large flat grating with ruled space 5^{cm} by 8^{cm}. Upon the margin of this grating Professor Rowland has written: "Definitions exquisite." The collimator and view telescope are combined in a single lens, an excellent objective by Wray, six inches in diameter, eight and a half feet focus. The radius of curvature of the back surface of this lens equals its focal length, so that the ray reflected from this surface passes back to the slit, and any objectionable illumination of the field is avoided. All parts of the instrument are so contrived that it is operated without the necessity of the observer leaving his seat at the eyepiece. A heliostat and achromatic lens of five feet focus form an image of the sun upon the slit. Thus arranged the instrument easily performs all tests of spectroscopic excellence with which the writer is familiar. To produce the metallic spectra an eight inch spark condensed by a number of jars having about 6 sq. feet of coated surface, has been employed. The spark is produced immediately before the slit, the jaws of which open equally. The coil is operated sometimes by a dynamo, and sometimes by the current from a storage battery. A review of all the spark spectrum lines has been made with the arc, and a few lines added to those that the spark gave. A steam jet* was employed to increase the luminosity of the spark. The work has been confined to the lower portion of the spectrum, where it still appears that eye observations have advantages of the photographs.

The position of a metallic line is determined by bringing the crosswire of the micrometer upon it, letting in the sunlight, and moving the crosswire to one of the standard lines

* This Journal, Feb., 1889.

of Rowland's tables. The true wave-length of the metallic line can then be computed from a previously determined micrometer constant. As a check to the result so obtained the metallic line has been interpolated, with the micrometer, between two of the standard lines in the same field of view, and the whole process has been repeated on different days until it became assured that positions of the metallic lines were as precise as those of the standard lines themselves.

Copper Spectrum.

The subjoined table gives the results as obtained for the spectrum of copper. The first two columns contain respectively the wave-lengths and intensities as given by Thalen; the third, the wave-lengths as determined in the present work.

Copper Spectrum.

Thalen λ.		Corrected λ.	Remarks.
6379·7	2	6380·899	Surrounded by continuous spectrum. Reversed in sun.
6218·3	5	------	No line seen.
5781·3	2	5782·285	Reversed in arc. Reversed in sun.
5700·4	1	5700·442	Reversed in arc. Reversed in sun.
		5535·64	Reversed in sun. Seen only in the arc.
		5555·119	Seen only in the arc.
5292·0	2	5292·68	Reversed in sun.
5217·1	1	5218·308	Reversed in arc. Reversed in sun.
5152·6	1	5153·345	Reversed in arc. Reversed in sun.
5104·9	1	5105·663	Reversed in sun.
5011·4	4	------	No line seen.
		5016·86	Seen only in the arc.
4955·5	3	------	No line seen.
4932·5	3	4933·181	Reversed in sun.

Zinc Spectrum.

The examination of the zinc spectrum is here limited to five lines; many of the remaining lines being mere dots close to the poles of the metal, others very broad and nebulous, and in general too ill defined to admit of measurement with the apparatus employed. In strong contrast to the remaining lines these five are very bright and sharp, and may be called the representative lines of the metal within those limits.

Zinc Spectrum.

Thalen λ.		Corrected λ.	Remarks.
6362·5	1	6362·566	Reversed in sun.
		6204·708	Faint but very sharp. Reversed in sun.
5893·5	2	5894·454	
4809·7	1	4810·671	Very bright. Reversed in sun.
4721·4	1	4722·306	Very bright. Reversed in sun.

Results of comparison with Solar Spectrum.—It will be seen by inspection of the tabulated results that nine out of the eleven lines of copper are reversed in the sun, and four of the five of zinc. The conclusion reached in each of these cases was after repeated examination when the conditions were such as to show a clear space between the components of the E line. The latest available authority* gives copper among the doubtful elements in a list of those found in the sun, and on the same list zinc does not appear at all. The present investigation makes it quite probable that zinc, and almost completely demonstrates that copper exists in the solar atmosphere.

Bowdoin College, March 14, 1889.

ART. L.—*On Allotropic Forms of Silver;* by M. CAREY LEA, Philadelphia.

SILVER is capable of existing in allotropic forms possessing qualities differing greatly from those of normal silver. There are three such forms, or rather three modifications of one form, differing from each other in many respects, but all more nearly related to each other than any one of them to normal silver. One of these forms is soluble in water, passing readily to an insoluble form, and this last may, by the the simple presence of a neutral substance exercising no chemical action upon it, recover its solubility. Another form closely resembles gold in color and lustre.

Whether metallic silver shall be reduced from its compounds in its normal or in an allotropic form, depends upon the reducing agent applied, so that it cannot be said with any certainty whether it exists in its compounds in its ordinary normal form, or in an allotropic condition: the latter alternative seems at least equally probable.

These allotropic forms of silver are broadly distinguished from normal silver by color, by properties, and by chemical reactions. They not improbably represent a more active condition of silver, of which common or normal silver may be a polymerized form. Something analogous has already been observed with other metals, lead and copper.

Much having been written, especially within the last few years, on the products of the reduction of silver compounds, a brief summary of what has appeared may be desirable before proceeding further. The study of this subject has led to remarkable divergencies of opinion on the part of the

* Young's General Astronomy.

chemists engaged in it. Almost all the views advanced have been successively disproved by each subsequent publication. It follows that what has obtained a place in the text books is almost wholly incorrect.

The earliest experimental work was Faraday's, but his product has been proved to be a mixture.* The next was the well known paper of Wöhler published in 1839. It is not my purpose here to enter upon a criticism of this memoir. If this illustrious chemist succeeded in obtaining by the means employed a true citrate of silver hemioxide,—as would appear from his analyses—no chemist since his time seems to have done so. The next publication to Wöhler's was that of Von Bibra, who used Wöhler's method and, whilst affirming that he obtained a similar citrate, found an entirely different constitution for the corresponding chloride. For instead of obtaining a hemichloride Ag_2Cl, he gives, as the result of 15 concordant analyses, the constitution of his product as Ag_4Cl_3.† A citrate, to yield such a chloride, (if such a chloride exists,) by the simple action of hydrochloric acid, could scarcely have the constitution assigned to it by both Wöhler and V. Bibra.

In 1882, Pillitz published two papers.‡ He commences by disputing the probability of the existence of Ag_4O on grounds of valency; namely as implying that oxygen may be quadrivalent. Although it is very doubtful that any one has up to the present time obtained Ag_4O, the argument seems futile as are many arguments deduced from supposed laws of valency. Similar reasoning would make Ag_2Cl impossible, which substance undoubtedly exists, and it would also deny the existence of K_2Cl which stands upon such authority as that of Rose, Kirchhoff, and Bunsen.§ Pillitz carefully examined the so-called hemioxide precipitated by alkaline solutions of antimony and tin and could find no trace of Ag_4O in any of them. He did not examine Wöhler's products.

The first person to deny categorically the existence of Wöhler's series of hemi-compounds of silver appears to have been Dr. Spencer Newbury. In two interesting papers,‖ he describes a repetition of Wöhler's methods and declares it to be impossible to obtain products of constant composition. The red solution taken by Wöhler to be argentous citrate, Dr.

* G. H. Bailey and G. J. Foster, Chem. Soc. 1887, 416. Bericht D. Ch. G., xx, Ref. 360.

† Erdmann, J. prakt. Chim. 1875, 120, 39. Von Bibra precedes his paper with a brief summary of the conclusions reached by previous chemists on the subject of the action of light and chemical reducing agents on silver compounds. The collection is interesting as showing to what inconsistent and even contrary opinions careful observers have come on these reactions.

‡ Zeitschrift für Ann. Chemie, xxi, p. 27, p. 496.

§ Gmelin Kraut, ii, 1, 72.

‖ Am. Chem. Jour. vi, 407; viii, 196.

Newbury concludes to be a suspension of finely divided silver. Muthmann* after a careful examination of Rautenberg's products concludes that that chemist was wholly in error in asserting the formation of compounds of chromic, molybdic and tungstic acids with silver hemioxide. He next studies the red liquid obtained by Wöhler's process and comes to the same conclusion as Newbury, that it consists of finely divided silver suspended in water.

I shall not dispute the correctness of this opinion in the case of the liquid examined by these two chemists. At the same time I cannot accept the tests of solution employed by Muthmann. That a substance will not pass through a dialyser shows that it is colloidal and is no proof whatever that it is not in solution. Animal charcoal takes up many substances from true solutions. Decolorization by animal charcoal is no proof whatever that the color removed was not in true solution. By freezing, the molecular condition of a substance may be changed. Muthmann found that when the red liquid was mixed with gum water and precipitated by alcohol, the precipitated gum carried down with it the red substance, thence deducing that it was only in suspension. This conclusion is scarcely justified. A solution of litmus was mixed with gum water and precipitated with alcohol: the mass of the litmus went down with the gum, a trace only appeared in the filtrate. With Hoffmann's violet, the same result. Yet no one, I think, will assert that these two substances do not make true solutions in water. Even however, if these arguments could be admitted they would not apply to the solutions presently to be described, which can be proved by optical means to be true solutions. I propose presently to show that silver may exist in a perfectly soluble form, dissolving easily and abundantly in water. Starting from this, it may show all degrees of solubility down to absolute insolubility, still however, existing in an allotropic form and quite distinct from normal or ordinary silver. The solutions formed are as perfect as those of any other soluble substance.

Wöhler's process was next repeated by G. H. Bailey and G. J. Foster, who came to the conclusion that no citrate of hemioxide was formed, and that Wöhler's results must be rejected.

Von der Pfordten† endeavored to obtain hemi-compounds of silver by acting on the nitrate with an alkaline solution of sodium tartrate, and also with phosphorous acid. His determinations were made volumetrically, based on an opinion that a permanganate solution acidified with sulphuric acid would dissolve silver hemioxide, but not metallic silver. Previously to receiving his paper I had found that sulphuric acid, even

* Bericht der D. Ch. Ges., xx, 983. † Ibid., xx, 1458.

diluted with ten times its bulk of water, was capable of acting on finely divided normal silver and of dissolving an easily recognized quantity. V. d. Pfordten's conclusions were thus vitiated entirely. It should however be remarked that the difficulties of the subject are extremely great. In his last paper* this chemist abandons his views as to the existence of silver hemioxide; so that at the present time the formation of Ag_4O by Wöhler's method, or by any other known metnod, is admitted by no one. That such an oxide may exist appears by no means improbable. The existence of Ag_2Cl and K_2Cl seems almost to involve that of Ag_4O and K_4O. This latter product Davy believed that he had obtained. The black substance which V. d. Pfordten formerly regarded as Ag_4O he now takes to be silver hydrate Ag_4H_2O.

The reduction products described by V. d. Pfordten are strongly distinguished from those which I shall presently describe by two decisive reactions:—

1. None of his products could be amalgamated with mercury (l. c., 2296). All of mine readily amalgamate.
2. None of my products give off the slightest trace of gas when treated with dilute sulphuric acid. All of his do so. (l. c., 2291.)

Moreover, the difference of appearance is extremely great.

Early in the year 1886, I took up the study of the reduction products of silver in connection with that of the photosalts. I commenced with Wöhler's process, giving it up after a few trials as affording no satisfactory results, and sought for a more reliable means. This I found, in March 1886, in a reaction which I still use; namely the reduction of silver citrate by ferrous citrate. At first, however, the results obtained were most enigmatical, the products very unstable, and impossible to purify. Much time was lost and the matter was given up more than once as impracticable. Eventually, by great modifications in the proportions, stable products, and capable of a fair amount of purification were got. Even the earlier and less pure forms were exceedingly beautiful; the purer are hardly surpassed by any known chemical products.

The forms of allotropic silver which I have obtained may be classified as follows:—

A. Soluble, deep red in solution, mat lilac, blue, or green whilst moist, brilliant bluish green metallic when dry.

B. Insoluble, derived from A, dark reddish brown while moist, when dry somewhat resembling A.

C. Gold silver, dark bronze whilst wet, when dry exactly resembling metallic gold in burnished lumps. Of this form there

* Ber. D. Ch. Ges., xx, 2288.

is a variety which is copper-colored. Insoluble in water, appears to have no corresponding soluble form.

Properties possessed by all the varieties in common and distinguishing them all from normal silver.

All these forms have several remarkable properties in common.

1. *That of drying with their particles in optical contact, and consequently, forming a continuous film.*—If either is taken in a pasty condition and is spread evenly over paper with a fine brush, it takes on spontaneously in drying a luster as high as that of metallic leaf. C when so treated would be taken for gold leaf. But this property is much better seen by brushing the pasty substance over glass. When dry, an absolutely perfect mirror is obtained. The particles next the glass, seen through the glass, are as perfectly continuous as those of a mercurial amalgam, and the mirror is as good. A and B form bluish-green mirrors, C, gold or copper-colored mirrors.

2. *The halogen reaction.*—When any of these allotropic forms of silver are brushed over paper and the resulting metallic films are exposed to the action of any haloid in solution, very beautiful colorations are obtained. The experiment succeeds best with substances that easily give up the halogen, such as sodium hypochlorite, ferric chloride, iodine dissolved in potassium iodide, etc. But indications are also obtained with alkaline salts such as ammonium chloride etc., though more slowly and less brilliantly. With sodium hypochlorite the colors are often magnificent, intense shades with metallic reflections, reminding one of the colors of a peacock's tail. Blue is the predominating tint. These are interference colors, caused by thin films, but whether of a normal silver haloid or a hemisalt, cannot be said. When silver leaf (normal silver) is fastened to paper and a comparative trial is made, the contrast is very striking.—This matter will be more particularly examined in the 2d part of this paper, and is mentioned here as one of the reactions distinguishing allotropic from ordinary silver.

3. *The action of acids.*—The stronger acids, even when much diluted, instantly convert the allotropic forms of silver into normal gray silver; even acetic acid, not too much diluted, does this. It is important to remark that this change takes place absolutely without the separation of gas. I have more than once watched the whole operation with a lens and have never seen the minutest bubble escape.

4. *Physical condition.*—All these allotropic forms of silver are easily reduced to an impalpable powder. One is surprised to see what is apparently solid burnished metal break easily to pieces and by moderate trituration yield a fine powder.

A. Soluble Allotropic Silver.

A solution of ferrous citrate added to one of a silver salt produces instantly a deep red liquid. (Ferrous tartrate gives the same reaction but is less advantageous.) These red solutions may either exhibit tolerable permanency or may decolorize, letting fall a black precipitate. It is not necessary to prepare the ferrous salt in an isolated form, a mixture of ferrous sulphate and sodic citrate answers perfectly.

When, however, concentrated solutions are used with a large excess of ferrous sulphate and a still larger one of alkaline citrate, the liquid turns almost completely black. It should be stirred very thoroughly for several minutes, to make sure that the whole of the precipitated silver citrate is acted upon by the iron. After standing for ten or fifteen minutes, the liquid may be decanted and will leave a large quantity of a heavy precipitate of a fine lilac-blue color. It is best to adhere closely to certain proportions. Of a ten per cent solution of silver nitrate, 200 c. c. may be placed in a precipitating jar. In another vessel are mixed 200 c. c. of a thirty per cent solution of pure ferrous sulphate and 280 c. c. of a forty per cent solution of sodic citrate. (The same quantity of ferrous sulphate or of sodic citrate in a larger quantity of water will occasion much loss of the silver product.) I think some advantage is gained by neutralizing the ferrous solution, which has a strong acid reaction, with solution of sodium hydroxide: as much may be added as will not cause a permanent precipitate. To the quantities already given, about 50 c. c. of 10 per cent soda solution. The reaction takes place equally well without the soda, but I think the product is a little more stable with it.—The mixed solution is to be added at once to the silver solution.

The beautiful lilac shade of the precipitate is rather ephemeral. It remains for some time if the precipitate is left under the mother water, but when thrown upon a filter, it is scarcely uncovered before the lilac shade disappears and the precipitate takes a deep blue color, without losing its solubility. It may be washed either on a filter or by decantation, with any saline solution in which it is insoluble and which does not affect it too much. On the whole, ammonic nitrate does best, but sodic nitrate, citrate, or sulphate may be used, or the corresponding ammonia salts. Although in pure water the precipitate instantly dissolves with an intense blood red color, the presence of five or ten per cent of any of these salts renders it perfectly insoluble. I have usually proceeded by adding to the precipitate (after decanting the mother water as completely as may be and removing as much more as possible with a pipette), a moderate amount of water; for the above quantities about 150 c. c. Much less would dissolve the precipitate but for the

salts present: this much will dissolve the greater part but not the whole, which is not necessary. A little of a saturated solution of ammonic nitrate is to be added, just enough to effect complete precipitation.

As the material appears continually to change, the amount of washing needed must depend upon the object in view. If wanted for analysis, the washing must be repeated many times until ferric salt ceases to come away, but no amount of washing will entirely eliminate it. After seven or eight solutions in pure water and as many precipitations, the material is to be thrown on a filter, the liquid forced out as completely as possible with a pump and then the ammonic nitrate washed out with 95 per cent alcohol until the filtrate leaves nothing on evaporation. The substance at this point is still soluble in water, though much less so than at first. During the washing the solubility slowly but steadily diminishes, a fact rendered noticeable by less and less ammonic nitrate being needed to precipitate it from its solution.

Analysis.—The product after thorough washing as above described with alcohol, was dried at ordinary temperatures or a little above, and was then reduced to very fine powder and washed again with water as long as anything dissolved. It was then dried at 100° C. in water bath. Three silver determinations were made.

A1	97·31	per cent silver.
A2	97·18	" "
B	97·21	" "

A1 and A2 were made with different portions of the same material, B with different material prepared in exactly the same way.

The substance therefore contained on an average 97·27 per cent of silver. The nature of the residue would decide whether the material was silver with a certain amount of impurity firmly attached to it, or whether we had to do with silver in chemical combination with other elements.

The filtrate from the silver chloride in analysis A2 was evaporated to dryness and was found to contain chiefly iron and citric acid. The iron was thrown down as sulphide, redissolved in nitric acid, precipitated hot, washed with boiling water and gave 0·8947. The residue therefore consisted of ferric oxide and citric acid, probably in the form of ferric citrate and attached so strongly that even the very careful and prolonged washing given failed to remove them. Stronger means would be required than could be used without altering the condition of the substance. The conclusion therefore seemed to be justified that the material consisted of uncombined silver simply mixed with impurity.

To verify this conclusion by additional evidence, the substance was examined as to its behavior when heated. For if any other element were chemically combined with the silver it would only be (in view of the high percentage of silver) hydrogen or oxygen. We might have to do with a hydride, analogous to Wurtz's hydride of copper, or possibly an oxide, but not probably as Ag_4O would contain only 96·43 per cent of silver.

The presence of either hydrogen or oxygen in combination with silver seems to be pretty certainly negatived by the action of dilute sulphuric acid on this (and the two other substances, B and C, to be described farther on). They are all converted into gray metallic silver without the slightest escape of gas. This seems tolerably conclusive in itself; and the result of exposing a great number of specimens of all the forms A, B and C to the action of heat was equally so. As the object was to expose the fresh and moist material to a gradually increasing heat from that of boiling water to a low red heat without interrupting the process, the following arrangement was found convenient.

A piece of Bohemian glass tube about six inches long was sealed in the lamp at one end, the other closed with a rubber cork, through which passed a small gas delivery tube and another tube passing into a small test tube partly filled with water and having another tube through the cork passing under the surface of the water, thus preventing regurgitation. The material was thus first exposed for some hours to a heat of about 150° C. in a chloride of calcium bath; this was next removed and the heat continued to low redness. Only traces of gas were evolved and this was found to be in all of the many trials made, carbonic acid, derived from the citric acid adhering. This treatment was repeated many times with all the different varieties of the substance and with the same result. The temperature was always raised sufficiently high to ensure the complete conversion of the material into normal gray silver, but in no case was oxygen or hydrogen set free.

It could not be overlooked that in all these trials the material had passed into an insoluble form before the silver determination was made. There remained therefore this possibility: that the silver, so long as soluble, might be in combination with citric acid and that its change to the insoluble condition was caused by its separating from the citric acid. It seemed desirable that this view should be tested. As the object was to determine the condition of the silver in the substance as originally formed, avoiding as far as possible to change that form by attempts at purification, the only course available was

to determine the ratio between the silver on the one hand and the citric acid on the other, either excluding from the determination, or else removing, that portion of the citric acid which was combined with sodium (sodic citrate being used in excess) or with iron. The first attempt was to exclude without removing it, by using Wolcott Gibbs's ingenious method of precipitating the base by hydrogen sulphide, and determining the acid thus set free in a solution originally neutral. It was ascertained by careful experiment on weighed quantities of pure anhydrous citric acid, that exact titration could be made with the aid of phenolphthalein. The silver was next redissolved and estimated as chloride. A large number of determinations were made, but the method proved unsatisfactory. It was found that portions of the same material operated upon separately gave different (even widely different) results. In fact, this very discordance was in itself a proof that no stœchiometrical combination existed between the silver and the citric acid.

The importance of the matter led me to take it up again with different means, estimating the citric acid by Creuse's method. In this method the solution, after being reduced to a small bulk, is exactly neutralized (with ammonia or acetic acid), is treated with a slight excess of barium acetate and then mixed with twice its bulk of 95 per cent alcohol, let stand a day and filtered and washed with 65 per cent alcohol. In igniting, a few drops of sulphuric acid convert the barium salt into sulphate in which form the estimation is made. A preliminary trial with a weighed quantity of citric acid showed that this method gave fairly good results. I was obliged to vary the method somewhat: the precipitate of barium citrate carried down with it enough iron to render it ochrey in appearance. It was, therefore, after thorough washing with 65 per cent alcohol till every trace of barium acetate was removed, dissolved on the filter with dilute hydrochloric acid (acid 1, water 10) in which barium citrate is extremely soluble and washed through. This was followed by still weaker acid and finally with water. From the filtrate, sulphuric acid precipitated snow-white barium sulphate.

But this method requires that both the sulphates and the excess of sodic and ferric citrate shall first have been perfectly removed. The blue precipitate was therefore washed with dilute solution of ammonic nitrate until this was effected. The necessity for this purification was regrettable as introducing a possibility of a change during the treatment. It was, however, indispensable that the ferrous, ferric and sodic citrates present should be got rid of. The material after this treatment was still freely soluble in water, to a dark-red solution. An ex-

amination of its absorption spectrum showed it to be still a true solution. From this solution the silver was first removed by H_2S and then the citric acid was determined in the above described way. (If the silver were thrown down by hydrochloric acid, the reliability of the citric determination would be impaired.) Next, the silver sulphide was converted into chloride and weighed. The result gave the ratio

1 gram silver to ·03195 gram citric acid.

In this case washing out the sulphates, etc., was an affair of several days. The work was repeated, reducing the time as much as possible. The material was precipitated, decanted as soon as settled, thrown upon a filter pump and the funnel kept constantly full of ammonic nitrate in dilute solution by a wash bottle. By using very thick paper and a powerful pressure the entire washing was rapidly finished so that in about six hours from first precipitation the material was thoroughly washed, redissolved and again filtered and placed under the action of H_2S. The result was

1 gram silver to ·0130 citric acid.

When these relations are reduced from weights to equivalents, they become:

No. 1, 1 equiv. citric acid to 55·63 equivs. silver.
No. 2, 1 " " 193·7 "

indicating both that the proportion of citric acid present is variable and that it is certainly not in stoichiometrical combination with the silver in the substance examined.

It has been already said that these solutions before being acted upon by H_2S were examined optically and found to be true solutions. The inference therefore seems to be very strong that there exists an allotropic form of silver freely soluble in water. This is a property so exceptional in a metal that I have admitted it with much hesitation. The principal arguments are as follows:

The content of silver in the various products was very carefully, and I believe I may say quite accurately, determined: it was extremely high, always above 97 per cent. As already remarked, this virtually excludes the presence of all elements except hydrogen and possibly oxygen. These elements were carefully searched for, but their presence could not be detected. To suppose that we had to do with a mixture in which some compound of silver was mixed with metallic silver was not possible, for as the whole was soluble we should still have to admit the solubility of silver.

We have consequently to deal with a substance containing over 97 per cent of silver, and neither hydrogen nor oxygen in

combination with it, the remaining 2 or 3 per cent fully accounted for by ferric oxide and citric acid determined as present as accidental impurity; the substance itself readily amalgamating with mercury by simple friction, nevertheless abundantly soluble in water. If I had been able to find any other explanation for these facts without admitting the solubility of silver, I should have adopted it. But none presented itself.

Whether in solution it exists as a hydrate, that is, in more intimate combination with one or more equivalents of water, cannot be said with entire certainty; but the easy amalgamation with mercury seems hardly to favor that view. No means could be found for settling the question absolutely. Certainly at 100° C. all water is expelled, but this is of course not an argument. All the water is not expelled by indefinite exposure to a vacuum over sulphuric acid. But the proportion left is very small.

The material examined was in all cases as nearly as possible the same as that originally precipitated, but absolute identity could not be obtained. The purification absolutely necessary effects some change. This is shown by the color. The freshly precipitated material dissolves to a blood red liquid, by great dilution yellowish red. The purified substance gives a darker red solution, which with dilution remains still red. Of the nature of the substances in the condition in which they were analyzed, I can speak with some positiveness, and these include a substance soluble in water and nevertheless appearing to be nearly pure silver.

The constitution of the lilac blue substance at the moment of formation and whilst still under its mother water is a matter of more difficulty; it could not be said with certainty that it was not in some way altered in the purification. Much time and labor were spent in endeavoring to settle this point, without entirely satisfactory results, and I am at present engaged in the search for a better method.

When this blue soluble substance, purified either by washing very moderately by ammonium nitrate, or by washing with pure water, using those portions which remain undissolved after most has been carried through the filter, is brushed over paper and dries rapidly, it exhibits a very beautiful succession of colors. At the moment of applying it appears blood red; when half dry it has a splendid blue color with a lustrous metallic reflection; when quite dry this metallic effect disappears and the color is mat blue. Examined with a polarizer it shows the same characters as to two reflected beams of light polarized in planes perpendicular to each other that are described further on under B.

When the blue substance prepared in either way dries more slowly in lumps the result is very variable; sometimes it is bright bluish metallic; sometimes dull lead color, with a metallic reflection only where it has dried against a smooth surface.

B. *Insoluble* ... *the foregoing.*

The solution of the blue product just described is influenced in a remarkable way by the addition of almost any neutral substance. So far I have not found any that does not precipitate it. Not only saline solutions do this, but even a solution of gum arabic.

Neutral salts may precipitate the silver in either a soluble or an insoluble form. Alkaline sulphates, nitrates and citrates throw down the soluble form, magnesium sulphate, cupric sulphate, ferrous sulphate, nickel sulphate, potassium bichromate and ferro cyanide, barium nitrate, even silver nitrate and other salts throw down a perfectly insoluble form. The soluble form constitutes a blue or bluish black precipitate; the insoluble, a purple brown, which by repeated washing, by decantation or otherwise, continually darkens.

What is very curious is that the insoluble form may be made to return to the soluble condition. Many substances are capable of effecting this change. Sodium borate does so, producing a brown solution, potassium and sodium sulphate produce a yellowish red solution and ammonium sulphate a red one. None of these solutions has the same blood-red color as the original solution; the form of silver seems to change with the slightest change of condition.

The solutions used must be extremely dilute, otherwise the silver, though rendered soluble in pure water by them, will not dissolve in the solution itself, a singular complication of effects. So that if a moderately strong solution of one of the above substances is poured over the insoluble silver substance it does not dissolve, but by pouring off the saline solution and replacing it with pure water, the substance now dissolves readily. The insoluble substance is also readily soluble in ammonia. The solution has a fine red color, and not the yellowish red of the sodium sulphate solution.

Most neutral salts act in one or other of the ways just described, precipitating the solution of the blue substance A in either the soluble or the insoluble form, the latter soluble in ammonia, but sodium nitrite is an exception; its solution effects an entire change and renders the substance wholly insoluble, probably reconverting it to normal silver.

Sometimes the substance will spontaneously pass into a soluble form. A specimen, rendered insoluble by precipitation with ferrous sulphate, after much washing began to run through, not only as a suspension, which often happens, but as a solution, clearing itself, after a day or two, of insoluble portions and furnishing a rose-red solution. I have kept this solution in a corked vial for eight months, during which time it has remained unchanged.

The general properties of this substance can be much better observed in the thin films obtained by brushing the moist substance over paper than in the lumps. The films thus obtained are bright greenish metallic, and this green evidently results from a mixture of blue and yellow, as in some lights the blue, in others the yellow, is most evident. When these films are examined by light reflected from them at a large incidence with the normal and a Nicol's prism or an achromatized prism of calc-spar is interposed between the film and the eye, it becomes at once apparent that the blue and yellow light are oppositely polarized. The yellow light is polarized in the plane of incidence, the blue light perpendicularly to that plane. All specimens show the yellow light, but the quantity of blue light is very variable and is directly connected with the amount of washing applied to the precipitate. The more it is washed the more the yellow predominates. To see the blue form in its full beauty, a little of the red solution may be precipitated with a very little magnesium or aluminium sulphate and be thrown on a filter. As soon as the liquid has drained off and without any washing, the deep bronze-colored substance is to be brushed over paper. On drying it has all the appearance of a bright blue metal with a remarkable luster. The mirrors obtained by brushing the substance over glass are so beautiful and so perfect that it seems as if this property might have useful applications, especially for silvering irregular surfaces. Much care, however, would be necessary in the preparation to obtain a permanent product.

Crystallization.—On one occasion this substance was obtained in a crystalline form. Some crude red solution had been set aside in a corked vial. Some weeks after, it was noticed that the solution had become decolorized, with a crystalline deposit at bottom. The bottle was carefully broken; the deposit, examined by a lens, consisted of short black needles and thin prisms. Evidently the saline matters present had balanced the silver in solution so nearly as not to cause an immediate precipitation, but a very gradual one only. The mother water was drained off and a few drops of pure water were added. No solution took place, the crystals were therefore of the material B, the insoluble form. The contact of pure water instantly

destroyed the crystallization and the substance dried with a bright green metallic luster. Contact with pure water evidently tends always to bring this form of silver into the colloidal state, sometimes soluble and sometimes not; whilst the contact with certain neutral salts renders it crystalline.

The extraordinary sensitiveness which allotropic silver shows to external influences contrasts strongly with the inertness of normal (probably polymeric) metallic silver. When we place this fact alongside of the well known sensitiveness of many silver compounds to light, heat and (as I have elsewhere shown) to mechanical force,* we are led to ask whether silver may not exist in this form in these very sensitive compounds.

To obtain the substance in a pure condition suitable for analysis, it is necessary to choose a precipitant not giving an insoluble product with either citric or sulphuric acid. Magnesium sulphate or nickel sulphate answers well; I have generally used the first named. A very dilute solution is made of it and the red solution of A is to be filtered into it. The precipitate soon subsides. A large quantity of water is to be poured on, and then washing by decantation can be continued to three decantations, after which the substance remains suspended. It can be made to subside by adding a very small quantity of magnesium sulphate; one four-thousandth part (0·25 gram to one liter) is sufficient. The substance may then be thrown on a filter and washed with pure water.

Analysis.—A specimen dried in vacuo over sulphuric acid gave

No. 1..... 97·17 per cent silver.
No. 2..... 97·10 " "

A specimen dried first in vacuo and then at 100° C., lost in the second drying ·88 per cent water.

So that the substance dried at 100° contained 97·96 per cent. of silver. The remaining 2·04 per cent consisted of ferric oxide and citric acid.

C. Gold-Yellow and Copper-colored Silver.

It has been long known that golden-yellow specks would occasionally show themselves in silver solutions, but could not be obtained at will and the quantity thus appearing was infinitesimal. Probably this phenomenon has often led to a supposition that silver might be transmuted into gold.† This yel-

* Production of an image on silver iodide capable of development by simple pressure.

† I have a little volume published in Paris in 1857 by a chemist named Tiffereau who was firmly convinced that in many reactions, minute portions of silver are converted into gold, especially with the aid of powerful sunlight. In Mexico, he affirmed, he had artificially produced several grams of gold, a portion of

low product, however, is only an allotropic form of silver, but it has all the color and brilliancy of gold, a fact which was apparent even in the minute specks hitherto obtained.

By the means presently to be described, silver can be converted wholly into this form. It is a little curious that its permanency seems to depend entirely on details in the mode of formation. I found many ways of obtaining it, but in a few months the specimens preserved changed spontaneously to normal silver. This happened even in well closed tubes. The normal silver produced in this way is exquisitely beautiful. It has a pure and perfect white color like the finest frosted jewelers' silver, almost in fact exceeding the jeweler's best products. I found, however, one process by which a quite permanent result could be obtained. Specimens made by it in November of 1886 are now, at the end of thirty months, unchanged.

In forming the blue product which I have called A, very concentrated solutions were necessary. C on the contrary is best obtained from very dilute ones. The following proportions give good results.

Two mixtures are to be prepared: No. 1, containing 200 c. c. of a ten per cent solution of silver nitrate, 200 c. c. of twenty per cent solution of Rochelle salt and 800 c. c. of distilled water. No. 2, containing 107 c. c. of a thirty per cent solution of ferrous sulphate, 200 of a twenty per cent solution of Rochelle salt and 800 of distilled water. The second solution (which must be mixed immediately before using only) is poured into the first with constant stirring. A powder, at first glittering red, then changing to black, falls, which on the filter has a beautiful bronze appearance. After washing it should be removed whilst in a pasty condition and spread over watch glasses or flat basins and allowed to dry spontaneously. It will be seen that this is a reduction of silver tartrate by ferrous tartrate. The metallic silver formed by reduction with ferrous citrate and ferrous tartrate is in an allotropic condition; with ferrous oxalate this result does not seem to be produced.

Although the gold-colored silver (into which the nitrate used is wholly converted) is very permanent when dry, it is less so when wet. In washing, the filter must be kept always full of water: this is essential. It dries into lumps exactly resembling highly polished gold, especially the surfaces that have dried in contact with glass or porcelain. For this substance has in a

which he presented to the French Academy with one of his papers. To his great disappointment he did not succeed in repeating these experiments in Paris, with more than an infinitesimal result. All gold in his opinion had been originally silver, and this belief, he affirms, is universal amongst Mexican miners. The book has for title "*Les Métaux sont des Corps composés.*"

high degree the property already described in forms A and B —that of drying with the particles in optical contact. When the thick pasty substance is extended over glazed paper, it dries with the splendid luster of gold leaf, with this essential difference, that these allotropic forms of silver B and C assume spontaneously in drying the high degree of brilliancy which other metallic surfaces acquire by elaborate polishing and burnishing. By brushing a thick paste of this substance evenly over clean glass, beautiful gold-colored mirrors are obtained; the film seems to be entirely continuous and the mirror is very perfect.

By continued washing the precipitate changes somewhat, so that in drying it takes on a coppery rather than a golden color, and is rather less lustrous, though still bright and permanent.

Two silver determinations by conversion into chloride made in Nov., 1886, gave:

No. 1..... 97·81 per cent silver.
No. 2..... 97·86 " "

Recently these experiments have been repeated and the washing was more successful. Ferric tartrate adheres very obstinately and after a time washing with water ceases to remove it. Stronger means cannot be employed without affecting the substance itself. These last determinations gave:

No. 1..... 98·750 per cent of silver.
No. 2..... 98·749 " "

The residue of No. 2 was examined and consisted almost wholly of ferric citrate.

Chestnut Hill, Phila., April, 1889.

NOTE.—The editors have received, from the author of the above paper, samples of the three allotropic forms of silver which he describes, and also strips of glass and paper coated with them. Mr. Lea is to be congratulated on his very important results. The coated strips, including the gold-colored mirror made with the "gold-silver," answer fully to his description. The mirror is remarkable for its perfection and brilliancy.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Composition of Water.*—Lord Rayleigh has communicated to the Royal Society the results of an attempt at an entirely independent determination of the relative weights of oxygen and hydrogen, by actual combustion of weighed quantities of the two gases. Dumas weighed only the oxygen and the water produced. Later investigators have weighed the hydrogen, either in the gaseous state as in the experiments of Cooke and the author, or occluded in palladium as in those of Keiser. As to the second weighing it is not material whether it relates to the water, as in the investigations of Cooke and Keiser; or to the oxygen as in the present experiments. In principle the method adopted by Rayleigh is very simple. Globes of the same size as those employed for the density determinations were filled to atmospheric pressure with the two gases and were then carefully weighed. By means of Sprengel pumps, the gases were exhausted into a mixing chamber, sealed below with mercury, where they were fired by electric sparks in the usual way. After sufficient quantities of the gases had been withdrawn, the taps of the globes were turned, the leading tubes and mixing chamber were cleared of all remaining gas, and, after a final explosion in the eudiometer, the nature and amount of the residual gas were determined. The quantities taken from the globes can be found from the weights before and after the operations. From the quantity of that gas which proved to be in excess, the calculated weight of the residue was subtracted. This gave the weight of the two gases which actually took part in the combustion. In practice, the mixing chamber, originally filled with mercury, was charged with equivalent quantities of the two gases; the oxygen being first admitted until the level of the mercury had dropped to a certain mark and then the hydrogen down to a second mark. The mixed gases might then be drawn off into the eudiometer and the chamber refilled; but to save time the chamber was replenished and the eudiometer filled from it simultaneously, the proper proportion of the gases being preserved by means of mercury manometers which indicate the pressures at any time in the globes. To obviate an accumulation of residual gas in the eudiometer, two sparking places were provided, one above the other, the lower one being generally used. When the tube contained excess of oxygen down to a point somewhat below the lower spark-wires each bubble of explosive gas readily found its way to the sparks and there was no tendency to a dangerous accumulation of mixed gas before an explosion took place. In consequence of the difficulties encountered, five results only have been obtained, representing the atomic ratio of oxygen and hydrogen as deduced immediately from the weighings with allowance for the unburned

residue. These are: 15·93, 15·98, 15·98, 15·93, 15·92; the mean of which is 15·95. Correcting for buoyancy, the final number for the atomic mass of oxygen is 15·89.—*Nature*, xxxix, 462, March, 1889. G. F. B.

2. *On Diamide hydrate and other salts.*—CURTIUS and JAY have continued their researches upon diamide N_2H_4, the compound isolated in 1887 by the former chemist.* Its intense attraction for water has rendered its preparation in the anhydrous condition extremely difficult; especially since water is also set free in all the reactions by which it is produced. On distilling diamide hydrochloride $\left\{\begin{matrix}NH_2.HCl\\NH_2.HCl\end{matrix}\right.$ with caustic lime in a silver retort, furnished first with a U-tube and then with a horizontal tube filled with quicklime, the liquid hydrate collected in the receiver. A strong solution of potassium hydrate, however, gave a larger yield. Diamide hydrate is a fuming liquid which boils without change at 119° and has a high refractive power. Glass is attacked by it readily and it rapidly destroys cork or caoutchouc. It is strongly alkaline, has a taste like ammonia, with a burning after-taste. It appears to be the strongest reducing agent known. It precipitates silver from a cold concentrated solution in fine compact crystalline masses and if the solution is dilute, in splendid mirror-like films. Platinic chloride is completely reduced by it with separation of metallic platinum. When dropped on mercuric oxide it explodes violently. The salts of diamide are well-marked and very stable. The di-hydrochloride $\left\{\begin{matrix}NH_2.HCl\\NH_2.HCl\end{matrix}\right.$ strongly resembles ammonium chloride, crystallizing in cubes and giving in films feathery crystals; but it is deliquescent. On heating to 198° it fuses, evolves hydrogen chloride, and leaves a clear glass of mono-hydrochloride $\left\{\begin{matrix}NH_2.HCl\\NH_2\end{matrix}\right.$. This on further heating breaks up into ammonium chloride, nitrogen and hydrogen. The normal hydrochloride gives no precipitate with platinic chloride but reduces it to platinous chloride, with evolution of nitrogen. Diamide sulphate $\left\{\begin{matrix}NH_2\\NH_2\end{matrix}\right.H_2SO_4$ crystallizes in forms which are optically bi-axial. It is only sparingly soluble in cold water and is thrown down when sulphuric acid is added to solutions of its salts. It fuses at 254° and is decomposed almost explosively, evolving sulphurous oxide, hydrogen sulphide and sulphur and leaving ammonium sulphite. The carbonate, nitrate, acetate and oxalate have also been obtained, all crystallized except the first, and all having strong reducing properties. When any salt of diamide is mixed with a nitrite, free nitrogen is evolved almost explosively.—*J. pr. Chem.*, xxxix, 27, 107; *Ber. Berl. Chem. Ges.*, xxii, 134 (Ref.), March, 1889. G. F. B.

3. *On the Synthesis of the Glucoses and of Mannite.*—By the action of barium hydrate upon acrolein dibromide E. FISCHER and

* This Journal, III, xxxiv, 226, Sept., 1887.

TAFEL obtained some time ago, two sugar derivatives in the form of their osazones, produced by precipitating with phenyl-diamide, which they called α-acrosazone and β-acrosazone respectively. The former these chemists have now further examined. By the action of hot concentrated hydrogen chloride, the α-acrosazone dissolves to a clear dark red liquid which on cooling deposits crystals of phenyl-diamide hydrochloride. The mother liquor is diluted, neutralized with lead carbonate, decolorized and precipitated with barium hydrate. The precipitate contains the α-acrosone, having the formula $CH_2 . OH . (CHOH)_3CO . COH$; which is an oxidation product of a simple sugar. The lead compound was decomposed with sulphuric acid, treated with barium carbonate, decolorized and evaporated to a syrup, which in the cold solidified to an amorphous mass. By warming the dilute solution of α-acrosone with zinc dust and acetic acid, it was reduced readily; and after removing the zinc by hydrogen sulphide, evaporation and extraction with absolute alcohol, ether produced a precipitate of the new sugar α-acrose in colorless flocks which soon deliquesced to a syrup. This substance shows the closest analogy with the glucoses. It tastes sweet, reduces Fehling's solution, and ferments with yeast. Moreover on reduction with sodium amalgam it yields a substance closely resembling mannite which the authors call acrite. Both acrose and acrite, however, are optically inactive; and this is the only respect apparently in which the former differs from the glucoses or the latter from mannite.—*Ber. Berl. Chem. Ges.*, xxii, 97, January, 1889. G. F. B.

4. *On Geometrical Isomerism.*—WISLICENUS and HOLZ have described a striking instance of geometrical isomerism in the case of the dibromide of crotonylene. In this form of isomerism, the compounds are precisely similar in their constitution and differ only in the relative positions of their atoms in space. By the direct action of bromine upon crotonylene $CH_3 . C \vdots C . CH_3$, a dibromide $CH_3 . CBr : CBr . CH_3$ is formed the atoms of which as the authors show, are arranged in space thus: $\begin{matrix} CH_3 . C . Br \\ \| \\ CH_3 . C . Br \end{matrix}$ the two similar groups being symmetrical with respect to an assumed plane between them. If, however, a dibromide be formed either by removing from crotonylene tetrabromide two of its bromine atoms, or by withdrawing from one of the tribrombutanes $CH_3 . CHBr . CBr_2 . CH_3$ a molecule of hydrogen bromide, the new dibromide is found to be quite a different substance from the first. While it has necessarily the same empirical formula, its boiling point was found to be about 3° higher than the other dibromide and it behaved quite differently on reduction with zinc dust. The authors can explain these differences only on the assumption that the arrangement of its atoms in space is centro-symmetrical $\begin{matrix} CH_3 . C . Br \\ \| \\ Br . C . CH_3 \end{matrix}$; and they give the name isocrotylene dibromide to

this compound. Both bodies on addition of bromine give the same tetrabromide $CH_3 . CBr_2 . CBr_2 . CH_3$.—*Ann. Chem. Pharm.*, ccl, 224, 230, Jan., 1889; *Nature*, xxxix, 467. G. F. B.

5. *On Aluminum acetyl-acetonate.*—Combes has recently produced an organic aluminum compound of some interest, since it seems likely to settle the disputed question of the valence of this metal. This compound is aluminum acetyl-acetonate, a white crystalline solid melting at 193°–194° and distilling unchanged at 314°–315°. Two density determinations by V. Meyer's method in nitrogen and at the temperature of boiling mercury gave values corresponding to the molecular masses 325·5 and 324·2; the molecular mass of $Al(C_5H_7O_2)_3$ being 324·5. Hence the triad formula is the only possible one even at this low temperature. There was no trace of decomposition.—*C. R.*, cviii, 405, Feb., 1889; *Bull. Soc. Chim.*, III, i, 343, March, 1889. G. F. B.

6. *Correction of Regnault's results upon the weight of gases.*—J. M. Crafts, following up the suggestion of Lord Rayleigh in regard to the effect of the presence of the atmosphere upon the vessel in which the gases were weighed by Regnault, finds the following corrected values for Regnault's results for density:

	Regnault.	Corrected.	Corrected value for weight of a liter.
Air	1·00000	1·00000	1·29349
N	0·97137	0·97138	1·25647
H	0·06977	0·06949	0·08988
O	1·10564	1·10562	1·43011
CO_2	1·52910	1·52897	1·97772

—*Comptes Rendus*, cvi, p. 1662–64, 1888. J. T.

7. *Iron spectrum.*—H. Kayser and C. Runge have issued a paper giving a catalogue of 4500 lines of iron based upon the absolute wave-length determinations of Rowland and Bell. Each line is characterized in the catalogue by its peculiarities as to sharpness and reversed nature, etc. The wave lengths were measured by Rowland's gratings and the limit of accuracy is $0{\cdot}01\mu\mu$. The authors believe that the iron lines will serve as reference lines for other workers in spectrum analysis. They hope to connect the spectra of other elements to the iron spectra by certain equations.—*Beiblätter Annalen der Physik und Chemie*, No. 2, p. 78, 1889. J. T.

8. *Electrical currents arising from deformation.*—The subject of the effect of torsion of bending and pressure upon the production of thermo-electric currents has been exhaustively studied by various writers. Ferdinand Braun has lately studied the subject anew and finds a remarkable example of these phenomena in nickel.—*Annalen der Physik und Chemie*, No. 5, pp. 97–127, 1889. J. T.

9. *Electrical dilatation of quartz.*—J. and P. Curie continuing their work upon this subject have constructed a manometer consisting of plates of quartz which are connected to a quadrant electrometer and are subjected to pressure. The sensitiveness of the apparatus is very great. With crystal plates having

7 square centimeters of base and a column of 10 centimeters in height the sensitiveness was such that the difference of potential corresponding to a striking distance of 1 millimeter between balls six centimeters in diameter gave a deviation of 25 centimeters upon the scale. The authors describe certain modifications of the apparatus. They are able to obtain instruments which are sensitive to 5 volts, and can serve to measure 1000 to 1500 volts. By altering the thickness of the plates of quartz, instruments of almost any suitable range can be constructed. The authors reply to a remark, that an optical manometer depending upon interference fringes might be made more sensitive than the *manomètre piézo-electrique*, which they describe, by stating that admitting that one can measure to $\frac{1}{100}$ of a fringe in the compensator of Babinet one could obtain a manometer sensitive to a pressure of three kilograms; whereas their electrical manometer is six hundred times more sensitive and indicates a pressure of five grams.—*Journal de Physique*, April, 1889, pp. 149–168. J. T.

II. Geology and Natural History.

1. *Triassic Plants of Eastern North America.*—Dr. Stur has reviewed (Verh. G. Reichsanst. July 31, 1888) the plants of the Triassic beds of Virginia described by Prof. Fontaine, with specimens before him, received, as he states, from Prof. Fontaine. He publishes the following list of species identified by him with species from the Lettenkohle, the lower division of the Upper Trias of Germany.

Clover Hill, near Richmond, Va.	Schists of Lunz.
Equisetum Rogersi Schimper.	*Equisetum arenaceum* Jæger.
Schizoneura Virginiensis Font.	*Calamites Meriani* Brgt.
Macrotæniopteris magnifolia Rogers.	*Tæniopteris latior* and *T. simplex* Stur.
" *crassinervis* Font.	?
Acrostichides Linnææfolius Bunb.	?
" *rhombifolius* Font.	*Speirocarpus Lunzensis* Stur.
" *densifolius* Font.	" *Rutimeyeri* Heer.
" *microphyllus* Font.	" *microphyllus* Stur.
Mertensides bullatus Bunb.	*Oligocarpia robustior* Stur.
" *distans* Font.	" *Lunzensis* Stur.
Asterocarpus Virginiensis Font.	*Asterotheca Meriani* Brgt.
" *platyrrachys* Font.	" "
" *penticarpus* Font.	" "
Lonchopteris Virginiensis Font.	*Sperocarpus Haberfelneri* Stur.
Clathropteris platyphylla Font.	*Clathropteris reticulata* Kurr.
Pseudo-danæopteris reticulata Font.	*Heeria Lunzensis* Stur.
Ctenophyllum Braunianum Font.	*Pterophyllum Riegeri* Stur.
" *grandifolium* Font.	" *Haueri* Stur.
Podozamites tenuistriatus Font.	?
Sphenozamites Rogersianus Font.	" *Bronnii* Schenk.

Relations are also shown between other American and German species, and the conclusion reached that the American beds are equivalents of the Lettenkohle.

In the same paper, Stur presents facts from the European Permian flora favoring the view that the Glossopteris flora of India, Afghanistan, Australia, and South Africa, is Permian.

2. *The Geological and Natural History Survey of Minnesota for the year* 1887. 504 pp. 8vo, with plates and other illustrations, N. H. Winchell, State Geologist: containing two reports on the Original Huronian rocks, and others referred to the Huronian, including the Animike group, the iron-bearing series, and underlying crystalline rocks, one by Prof. N. H. WINCHELL, and the other by Prof. A. WINCHELL; and also a report on the crystalline rocks by H. V. WINCHELL.

Field Studies in the Archæan Rocks of Minnesota with accessory observations in Ontario, Michigan and Wisconsin, by ALEXANDER WINCHELL. 504 pp. 8vo, Ann Arbor, 1889.

The second of these volumes consists of the reports of Prof. A. Winchell for the years 1886 and 1887 to the Minnesota reports of those years. The investigation of the "Original Huronian" by Professors N. H. and A. Winchell has led them to similar conclusions. The results are here cited from the report of the latter. The section made conforms in most points with the descriptions by Logan in 1863, and on his map of 1865. The succession of rocks commencing with the oldest, and excluding, as igneous, the chlorite rocks and greenstones, is stated to be as follows:

1. Missisagui quartzyte, 3750 feet thick; 2, Bruce limestone 100 ft; 3, Lower slates or argillyte, conglomeritic and siliceous, 7400 ft; 4, Red felsyte, granulyte and quartzyte, 100 ft; 5, Upper Slates or argillyte; 6. Otter-tail cherty limestone, 100 ft; 7, Thessalon quartzyte, red and gray, 5000 ft; 8, Otter-tail quartzyte, white, 4000 ft. None of the rocks are crystalline, except locally at a contact with an eruptive. The White quartzyte, the uppermost stratum, occupies the north shore as far as St. Mary's River and along part of St. Joseph's island. Here it is overlaid directly by a siliceous fossiliferous limestone, apparently the Chazy, and hence it is probably Lower Cambrian.

From a study of the Marquette iron region, the conclusion is deduced that the rocks underlie the true Huronian, and are unconformable to it, while "not separated from the Laurentian by a structural unconformability." The Animike formation, on the north shore of Lake Superior, which stretches from Thunder Bay nearly to Duluth, and is recognized still farther west, is essentially argillitic, with siliceous layers, and with some iron-ore (magnetitic beds) in the upper part, and is generally nearly horizontal in bedding. It is made the equivalent of the "slate conglomerate" of the typical Huronian. The Kewatin series of argillitic, sericitic, chloritic and micaceous schists, high in dip, occurring about Vermillion Lake and elsewhere (and including the so-called Vermillion series), is an independent system older than and unconformable to the Animike. The Ogishke conglomerate of the vicinity of Ogishke-Muncie Lake, with the associated slates, is perhaps of the Animike series, but probably underlies it.

Many important facts are detailed and illustrated in the reports with regard to the relations of granite to the schists, and to breccia granite, and conglomerate granite, and also to gradual transi-

tions between the schists of various constitutions—such as from "earthy and sub-crystalline schists to gneiss"—facts which no mode of applying pressure will explain.

In a general section of the Huronian and older formations, concluding the paper, the "Marquettian" iron-bearing system, consisting of sericitic and argillitic rocks with the Ogishke conglomerate, is introduced below the typical Huronian (Cambrian) and over the older crystalline rocks (Vermillion series, etc.) of the Archæan. The authors also conclude from their study of the crystalline rocks that the older crystalline schists, or the Archæan, were originally sediments, and that this is true of the gneisses, even those fading into granite.

3. *Bömmelöen og Karmöen med omgivelser geologisk beskrevne* af Dr. HANS REUSCH. 422 pp. 8vo, with 3 colored maps and 205 illustrations in the text. A summary of the contents in English occupies pages 385 to 422. Published by the Geological Survey. Kristiania, 1888. (P. F. Steensballes).—This very instructive contribution to the geology of crystalline rocks is the result of a thorough investigation of the islands at the mouth of the Hardanger Fiord, on the coast of Norway, just south of Bergen, embracing Bömmelö, Karmö, and others in the vicinity. The rocks are granite, gneiss, dioryte, mica, hydromica, hornblende, argillitic and other schists, quartzytes, conglomerates, limestone, gabbro, with serpentine, diabase and other kinds. The granite and gneiss are in part Archæan. The other rocks are found to be in part Primordial and Upper Silurian by the presence of fossils, which occur as reported in Dr. Reusch's memoir of 1862, in the finer schists and limestone. The Primordial localities occur 130 kilometers to the eastward; but the schists are probably the same that exist in the Bokne fiord east of Karmö. The Upper Silurian fossils (of which figures are here given) were found near Bergen and in the southern parts of the islands of Storen and Bömmelö. The various details with regard to the structure of the rocks are described and well illustrated—their transitions, irregularities of flexures and faults, pressure-deformation producing elongations and compressions of pebbles, crystals and fossils, pressure-made breccia in the granite and gneiss, and other rocks, and bowlder-made granite, veins of various forms and irregularities, dikes, alterations of the rocks, diabases altered to hornblende rocks, and also to potstone, gabbro to serpentine, and so on. The rocks are regarded as for the most part of one geological series; and the conclusion is presented that the region "participated in the great post-Silurian folding-process of the Scandinavian peninsula," the main trend of whose axis was N.E. The occurrence of granite inter-bedded with masses of amphibolyte, serpentine, calciferous crystalline schists, limestone is regarded as evidence that the granite as well as the other rocks were originally of fragmental origin. The author recognizes the fact that "in some cases, originally sedimentary rocks may be regionally metamorphosed and at last be protruded as true eruptives."

4. *Composition of a brick from the brick-yard of S. P. Crafts, at Quinnipiac, three miles north of New Haven, Ct.;* by O. H. DRAKE.—The brick-clay used for making the bricks is from the bed of stratified drift in which were found bones of the Reindeer, mentioned in volume x (1875) of this Journal. The brick was one of the overbaked kind, much distorted, and highly vesicular or scoria-like, and the texture within indicated complete fusion. The clay had been mixed with coal-dust before the heating, as now usual at brick yards. The analysis of the vesicular semi-glassy portion afforded

SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	K_2O	Na_2O
65·89	18·98	2·97	1·32	0·22	2·29	2·56	3·15	2·96=100·32

The large percentage of potash and soda shows that the clay contained much undecomposed feldspar, which is natural in view of the fact that the crystalline rocks that were its source border the Connecticut valley through its whole distance to New Haven. The vesiculation is supposed to be due to the coal dust.

5. *International Congress of Geologists.* (From a communication from the Secretary of the American Committee, Professor H. S. Williams, to the Editors.)—The Organizing Committee of the International Congress of Geologists met in the National Museum, Washington, D. C., on the 19th of April last. Present, Professor J. S. Newberry (in the chair), J. P. Lesley, N. S. Shaler, O. C. Marsh, C. H. Hitchcock, J. J. Stevenson, G. K. Gilbert, James Hall, A. Heilprin, J. R. Proctor, A. Winchell, C. D. Walcott, R. P. Whitfield and H. S. Williams.

Professor J. S. Newberry of Columbia College was elected Permanent Chairman, G. K. Gilbert of the U. S. Geological Survey, Vice-Chairman, and H. S. Williams of Cornell University, Secretary.

There were added, by election, three new members to the Committee, T. Sterry Hunt, Persifor Frazer and E. D. Cope, making a total of twenty-seven.

It was resolved that the Chairman appoint three committees, viz: (1) a Committee on the Scientific programme of the Congress, (2) a Committee to arrange for the longer excursions, (3) a Local Committee to make arrangements for the holding of the meeting in Philadelphia. The names of the members of these sub-committees will be announced later.

The Committee adjourned to meet at Philadelphia at the time, in November, of the meeting of the National Academy.

6. *Brief notices of some recently described minerals.* METASTIBNITE.—This name has been proposed by Becker for the red sulphide of antimony which he has observed among the deposits of the Steamboat Springs, California. It is brick-red in color, dull in luster, apparently amorphous, and occurs mingled with silica and sulphide of arsenic. It seems to be identical with the chemically precipitated Sb_2S_3.—*U. S. Geol. Surv., Monograph* xiii.

HELIOPHYLLITE, RHODOTILITE.—Two new minerals from Pajsberg, Sweden, described by G. Flink. Heliophyllite is a sulphur-yellow mineral, with foliated structure, and optically shown to

belong to the orthorhombic system. Hardness = 2; specific gravity = 6·886. An analysis yielded:

As_2O_3	PbO	MnO, FeO	Cl
11·69	80·70	0·54	8·00 = 100·93

The formula deduced is $Pb_4As_2O_7+2PbCl_2$. It is probably identical with a mineral noted by Nordenskiöld as occurring with eedemite at Långban.

Rhodotilite is a rose-red radiated mineral with silky luster; it is referred on the basis of an optical examination to the triclinic system. Hardness = 4 – 5; specific gravity = 3·03. An analysis yielded:

SiO_2	MnO	FeO	CaO	MgO	PbO	H_2O
43·67	37·04	1·11	9·38	0·15	0·77	7·17 = 99·29

The formula deduced is $2(Mn,Ca)SiO_3+H_2O$. — *Œfv. Ak. Stockh.*, Nov., 1888.

Inesite.—A hydrated silicate of manganese and calcium, apparently the same mineral as that later called rhodotilite by Flink. It occurs in fibrous radiated forms of a flesh-red color with other manganese ores in the Dillenburg region, Germany. It is referred to the triclinic system as the result of the optical examination. Hardness, 6–7; specific gravity, 3·103. Analysis:

SiO_2	MnO	FeO	CaO	MgO	H_2O	Al_2O_3
43·92	38·23	0·69	8·00	0·28	8·49	0·29=99·85

Described by A. Schneider in *Zeitschr. Geol. Ges.*, vol. xxxix, 829, 1888. Cf. also Flink, *Œfv. Ak. Stockh.*, Jan. 9, 1889.

Caryopilite (Karyopilite).—A hydrated silicate of manganese allied to inesite. It occurs in botryoidal or reniform shapes, having a matted fibrous structure, at the Harstig mine, near Pajsberg, Sweden. The color is brown, the hardness 3·5, and the specific gravity 2·83–2·91. Analysis:

SiO_2	MnO	MgO	CaO	PbO	Fe_2O_3	Al_2O_3	Alk.	H_2O	Cl
36·16	46·46	4·80	0·28	0·37	1·33	0·35	0·20	9·81	0·09=99·85

Approximate formula, $4MnO.3SiO_2.3H_2O$. Described by A. Hamberg in *Geol. För. Förhandl.*, vol. xi, 27, 1889.

Ochrolite.—An antimonate of lead from Pajsberg, isomorphous with heliophyllite (see above). It occurs in tabular orthorhombic crystals, of a sulphur-yellow color, and adamantine luster. An analysis gave: PbO 76·52, Cl 7·72, Sb_2O_5 17·59 (as loss), leading to the formula $Pb_4Sb_2O_7+2PbCl_2$. Described by G. Flink in *Œfv. Akad. Stockh.*, Jan. 9, 1889.

Facellite.—Described by E. Scacchi (Rend. Accad. Napoli. Dec. 1888) as a new mineral from Mt. Somma. It occurs in colorless and slender acicular crystals, optically uniaxial, and probably belonging to the hexagonal system. Hardness about 6; specific gravity 2·493. An analysis yielded:

SiO_2	Al_2O_3	K_2O	Na_2O
37·73	33·09	29·30	0·37 = 100·49

This corresponds to the formula $KAlSiO_4$ or $K_2O.Al_2O_3.2SiO_2$. The author has evidently overlooked the description of *Kalio-*

philite (cf. this Journal, xxxiii, 423) by Mierisch, which is from the same locality and is doubtless the same mineral.

PAPOSITE.—A hydrous iron sulphate from the Union mine near Paposa, Atacama. It occurs in dark red crystalline masses having a fibrous radiated structure. Its composition is expressed by the formula $2Fe_2O_3 . 3SO_3 . 10H_2O$. DARAPSKY, Jahrb. Min., i, 23 ref., 1889.

7. *Mazapilite.*—Dr. KOENIG has continued his investigation of this species from Mazapil, Mexico (see vol. xxxvi, p. 391). It proves to be orthorhombic with a prismatic angle of 119° 50′. An analysis gave:

As_2O_5	Sb_2O_5	P_2O_5	Fe_2O_3	CaO	H_2O
43·60	0·25	0·14	30·53	14·82	9·83 = 99·17.

It thus approaches very close to arseniosiderite, and may be identical with it.—*Proc. Acad. Nat. Sci. Philad.*, 45, 1889.

8. *Gahnite, Columbite.*—Dr. GENTH describes gahnite from Smedley's quarry, Delaware Co., Penn., and columbite from Mineral Hill. The latter mineral is especially interesting as being a nearly pure niobate with Nb_2O_5 76·26 p. c., Ta_2O_5 0·83 p. c.; the specific gravity, 5·26, is correspondingly low.—*Proc. Acad. Nat. Sci., Philad.*, 50, 1889.

9. *Stibnite from Canada.*—In the Annual Report of the Geology of Canada for 1887, G. CH. HOFFMANN, chemist to the Survey, announces the occurrence of stibnite at Foster's Bar, about 23 miles from Lytton, Br. Columbia.

10. *Mineralogy of Pennsylvania*, Part I. Easton, Penn.—Professor JOHN EYERMAN has prepared this pamphlet as a continuation of Dr. Genth's volume on the same subject issued in 1875. The finding of euxenite is announced, but from an unknown locality, also of erythrite at the French Creek mines. The following analysis is given of the calamine from Friedensville: SiO_2 24·32, ZnO 65·05, H_2O 7·86, Fe_2O_3 2·12 = 99·35.

11. *Note on Sinter-forming Algæ.*—A collection of Algæ from the hot springs of the Yellowstone National Park, has been placed in the hands of Professor W. G. Farlow, for examination. The result of his study will be published on the completion of the work together with such facts concerning the occurrence of the plants as Professor Farlow may care to use. The specific determination of Calothrix, and of Leptothrix, given in the article on the "Formation of Siliceous Sinter," in this volume, were not made by him, and are subject to correction in his report.

W. H. WEED.

12. *Results obtained by etching a sphere of quartz and crystals of quartz with hydrofluoric acid;* by Dr. OTTO MEYER and SAMUEL L. PENFIELD.—Starting with a sphere of quartz, shown by its pyro-electrical behavior to have been cut from a simple right-handed crystal, the authors have studied the effects of exposing it to the action of hydrofluoric acid for different periods from four days to eight weeks. Two excellent plates reproduce with wonderful fidelity the delicate etchings exhibiting the tetar-

tohedral symmetry of the crystal, which were obtained in the successive steps of the process. Perhaps the most remarkable point brought out is the resistance to attack at an extremity of each of the three lateral axes, while in the direction of the vertical axis the solution went on very rapidly. Thus in the later stages of the process, after seven weeks, the sphere was flattened to about one-half its original diameter vertically, while in the transverse direction it had almost a triangular form.—*Trans. Conn. Acad.*, vol. viii, 1889.

13. *Seventh Annual Report of the Directors of the United States Geological Survey*, W. POWELL, 656 pp. roy. 8vo.—After a review of the organization of the Survey, and a statement of the work in progress and partly accomplished, and the reports for the year 1886 of the heads of divisions, this report contains the following elaborate papers: The Rock-Scorings of the Great Ice-Invasions, by T. C. CHAMBERLIN; Obsidian Cliff, Yellowstone National Park, by J. P. IDDINGS; Geology of Martha's Vineyard, by N. S. SHALER; Classification of the early Cambrian and pre-Cambrian formations—a brief discussion of principles illustrated by examples drawn mainly from the Lake Superior Region, by R. D. IRVING; The Structure of the Triassic formation of the Connecticut Valley, by W. M. DAVIS; and the Geology of the Head of the Chesapeake Bay, by W. J. McGEE. There is also a valuable paper on Salt-making processes in the United States by T. M. CHATARD. Many fine plates and cuts, mostly from photographs and maps, illustrate these papers. Those of the paper by Chamberlin are very beautiful and effective; so also those of the Obsidian Cliff showing its columnar features, its lithophyses and spherulites; and those of the other papers have great interest. Portions or abstracts of the papers of Iddings, Irving, Davis and McGee have appeared in this Journal. A general map of glacial striæ in the United States accompanies Mr. Chamberlin's paper.

14. *Journal of Morphology.*—The number just issued (No. 3 of vol. ii), of the always excellent Journal of Morphology, of Boston, (published by Ginn & Company), contains an elaborate and admirably illustrated paper by C. S. MINOT on the uterus and embryo, I, Rabbit, II, Man; another, of like character, by E. P. ALLIS, JR., on the anatomy and development of the lateral line system in Amia Calva; the two covering 228 pages and illustrated by many plates and figures in the text; besides shorter papers on the organization of atoms and molecules by Prof. A. E. DOLBEAR; some new facts about the Hirudinea by C. O. WHITMAN, and Segmental sense-organs of Anthropods, by WM. PATTEN.

15. *On the Development of Manicina areolata;* by HENRY V. WILSON.—This is another of the profound researches published in the Journal of Morphology, in vol. ii, No. 2. The paper is the thesis for the degree of Doctor of Philosophy, at the Johns Hopkins University, honored by the University a year since. It is a study of the embryological development of the species of

coral mentioned, during the spring of 1887, at the Marine Laboratory of the University stationed on the island of New Providence, Bahamas. It is illustrated by seven folded plates.

16. *The Anatomy of Astrangia Danæ.* Six lithographs from drawings by A. Sonrel, Natural History Illustrations prepared under the direction of Louis Agassiz, 1849. Explanation of plates (20 pages 4to) by J. Walter Fewkes. Published by the Smithsonian Institution, 1889.—The beautiful plates here issued were drawn in 1849 under Prof. L. Agassiz's direction from material collected during the first dredging trip of Prof. Agassiz under the auspices of the U. S. Coast Survey. The vessel, the steamer Bibb, was under the command of Lieut. C. H. Davis, and the collections of Astrangia were made near Nantucket. The memoir was left unfinished by Prof. Agassiz.

III. Miscellaneous Scientific Intelligence.

1. *The International Congress of Electricians* will meet in Paris during the week from the 24th to the 31st of August next. The subjects to be considered are Measurements, Machines, Electrochemistry, Lighting, Telegraphy, Telephony and other economic applications of electricity and Electrophysiology. The fee for membership is twenty francs. All communications relative to the Congress should be addressed to M. Mascart, President of the Committee of Organization, 44 Rue de Rennes, Paris. The purpose of the meeting is to continue and complete the work of the Reunion of 1881.

2. *Geological Society of France.*—The Special Reunion of this Society will be held this year at Paris, commencing with August 18th. There will be excursions to the various localities of interest about Paris, and also under the guidance of MM. Michel Lévy and Barrois, in Auvergne and Brittany. Communications should be addressed "Secretariat de la Société geologique, 7 Rue des Grands-Augustins." American geologists have been invited, through Major Powell, President of the American Association, to attend the reunion.

3. *The Botanical Society of France,* according to a circular recently issued over the signature of M. H. de Vilmorin, President of the Society, will have a Reunion during the latter half of the month of August. M. Maury is Secretary of the Committee of Organization.

4. *American Geological Society.* The regular meeting of this Society will be held at Toronto, Canada, on the 28th and 29th of August next. The circular issued by the Secretary, Prof. J. J. Stevenson, of the University of the City of New York, requests that a member having a paper to read should send him an abstract of its contents and an estimate of its length before the 10th of August; and where the author of a paper will not be present, that the paper be sent to him, by the same date, that it may be submitted to a meeting of the Council.

5. *J. A. Berly's Universal Electrical Directory and Advertiser.*—The electrician's *vade mecum*, containing a complete record of all the industries directly or indirectly connected with electricity and magnetism, and the names and addresses of manufacturers in Great Britain, America, the Continent, etc. 437 pp. 8vo. London, 1889: Wm. Dawson & Sons.—This is the eighth annual issue of this valuable directory. Its comprehensive character can be inferred from the title.

6. *Stellar Evolution and its relations to Geological Time*, by James Croll, LL.D., F.R.S., author of "Climate and Time," "Climate and Cosmology," "Philosophy of Thesim," etc. 118 pp. 12mo. 1889. London (E. Stanford).—The subjects of this volume by Dr. Croll, are: the probable origin of meteorites, comets and nebulæ, and the source from which the sun derived his energy; secondly, the evidence in support of the theory advocated derived from the testimony of geology and biology as to the age of the sun's heat; and thirdly questions relating to the pre-nebular condition of the universe, and the bearing which these have on theories of stellar evolution. Other related subjects will be considered, the Preface states, "in a future volume, 'Determinism, not force, the Foundation Stone of Evolution,' a work of a more general and abstract character, which was commenced many years ago."

7. *Graphics, or the art of Calculation by drawing lines, applied especially to Mechanical Engineering: with Atlas of Diagrams;* by Robert H. Smith. Part I, 8° and 4°, Longmans. London, 1889.—The method of representing forces and other directed quantities by lines is familiarly used in every elementary text-book in statics. The determining of the magnitude of unknown quantities by geometrical constructions is older than what we know as arithmetic. But the full application of graphical methods to problems in which the quantities need be known only to two or three significant figures, particularly to engineering problems, has greatly increased since the publication of Culmann's *Graphische Statik* in 1875. That work beautifully exhibited the power which graphical construction possesses for the investigation of practical problems. A list of the more important subjects treated by Mr. Smith in this first part will show the scope of his work. He treats of Graph-Arithmetic, Graph-Algebra, Grapho-Trigonometry, Vector and Rotor addition, the Kinematics of Mechanism, flat linkages without and with beam links, and solid static structures. A second part is promised in case this volume meets with a favorable reception. It will deal mainly with synthetic problems, and with the design of structures and machines.

OBITUARY.

Frederick A. P. Barnard, President of Columbia College, New York, for twenty-five years, died on the 27th of April, at the age of eighty.

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